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RODGERS, W. L., Midn Naval Observatory.
ROELKER, C. R., P. A. Engnr. Navy Department.
ROHRBACKER, J. H., C. Midn. "Pensacola."
ROOSEVELT, N. L., Esq. No. 52, William St., N. Y.
ROSS, A., Lieut. Portsmouth.
ROWAN, S. C., Vice Adm. Navy Department.
RUSH, R., Lieut. Naval Academy,
RUSH, W. R., Midn. "Constitution."
RUSSELL, B. R., 1st Lieut. U. S. M. C. "Galena."
RUTH, M. L., Surg. Naval Academy.
SAFFORD, W. E., C.Midn. Powhatan.
SAMPSON, W. T., Comdr. "Swatara."
SANDS, B. F., Rear Adm. No. 816, 15th Street, Washington.
SARGENT, N., Master. "Portsmouth."
SAWYER, F. E., Master. "Ashuelot."
SCHAEFER, H. W., Lieut. Naval Academy.
SCHETKY, C. A., Lt. Comdr. "St. Louis."
SCHOCK, J. L., C. Midn. Naval Academy.
SCHOULER, J., Lieut. Comdr. Naval Academy.
SCHROEDER, S., Lieut. Hydrographic Office.
SCOT, J. A., P. A. Engr. League Island Yard.
SEBREE, U., Lieut. Coast Survey Office.
SELFRIDGE, J. R., Lieut. "Portsmouth."
SELFRIDGE, T. O., Rear-Adm. No. 2013, I St. Washington.
SHARP, ALEXANDER, Ensign. "Pensacola."
SHAW, C. P., Lieut. Navy Department.
SHEPARD, E. M., Comdr. Naval Academy.
SHOCK, W. H., Engineer in Chief. Navy Department.
SICARD, M., Comdr. Navy Yard, Boston.
SIGSBEE, C. D., Lt. Comdr. Hydrographic Office.
SIMPSON, E., Commo. League Island Yard.
SIMPSON, E. jr., C. Midn. "Richmond."
SKERRETT, J. S., Capt. Light-House Inspector, Portland, Me.
SKINNER, A. N., Astronomer. Naval Observatory.
SLACK, W. H., Master. No. 714, 18th St., Washington.
SLOANE, J. D., Asst. Engnr. "Ranger."
SMITH, A. E., C. Engnr. "Despatch."

SMITH, D., Chief Engnr. "Nipsic."
SMITH, J. A., Pay Insp. Navy Pay Office, Washington.
SMITH, W. D., Chief Engnr. "Yantic."
SMITH, W. STROTHER, C. Engnr. "Pensacola."
SMITH, W. STUART, C. Engnr. Naval Academy..
SNYDER, H. L., Chief Engnr. "Minnesota."
SOLEY, J. C., Lieut. "Saratoga."
SOLEY, J. R., Professor. Naval Academy.
SOUTHERLAND, W. H. H., Master. "Kearsage."
SPEEL, J. N., P. A. Paym. Navy Department.
SPERRY, C. S., Lieut. "Richmond."
SPEYERS, A. B., Lieut. "Saratoga."
SPRAGUE, F. J., Midn. "Minnesota."
SPRAGUE, J. P., Chief Engnr. Naval Academy.
STAHL, A. W., C. Engnr. "Galena."
STANTON, J. R, P. A. Paym. "Kearsage."
STANTON, O. F., Capt. "Constitution."
STAUNTON, S. A., Master. "Swatara."
STAYTON, W. H., C. Midn. Naval Academy.
STEVENS, T. H., Rear-Adm. "Pensacola."
STEVENS, T. H., Lieut. "Pensacola."
STEWART, H. H.. Chief Eng. No. 1707, S. Broad St., Phila.
STEWART, ROBERT, C. Engnr. Naval Academy.
STOCKTON, C. H., Lieut. Navy Yard, Washington.
STOCKTON, H. T., Lieut. Asiatic Station.
STRONG, E. T., Lieut. Navy Yard, Boston.
STRONG, W. C., Lieut. "Wyoming."
SULLIVAN, J. T., Lieut. Washington Yard.
SUTTON, F. E., C. Midn. Naval Academy.
TANNER, Z. L., Lieut. Steamer Fish-hawk.
TAUSSIG, E. D., Lieut. Naval Academy.
TAYLOR, H. C., Lieut. Comdr. "Saratoga."
TERRELL, T. C., Lieut. Pensacola Yard.
TERRY, E., Commander. Los Angelos, Cal.
TERRY, N. M., Professor. Naval Academy.
THACKARA, A. M., Lieut. Hotel Vendome, Boston.
THOMAS, C., Master. Nautical Almanac Office.
THOMAS, C. M., Lieut. Comdr. Naval Academy.
THOMAS, E. B., Lieut. Coast Survey Office.
TILLEY, B. F., Lieut. Naval Academy.
TILLMAN, E. H., Midn. "Shenandoah."
TILTON, McL., Captain M. C. Marine Barracks, Washington.
TOTTEN, G. M., Lieut. "Tennessee."
TRAIN, C. J., Lieut. Comdr. Naval Academy.
TRIBOU, D. H., Chaplain. Navy Yard, Boston.
TRILLEY, J., Chief Engnr. "Wabash."
TRUXTUN, W. T., Captain. Navy Yard, Norfolk.

TRYON, J. R., SURGEON. Sturdevant House, New York.
TURNBULL, FRANK, LIEUT. Morristown, N. J.
TURNER, T. J., MED. DIR. Navy Department.
TURNER, W. H., LIEUT. Navy Yard, Portsmouth.
TYLER, A. C., ESQ. Norwich, Conn.
TYLER, G. W., LIEUT. Naval Academy.
UPSHUR, J. H., COMMO. Europe.
VAN DUZEN, L. S., C. MIDN. "Powhatan."
VERY, E. W., LIEUT. Navy Signal Office.
VREELAND, C. E., MASTER. "Ticonderoga."
WADHAMS, A. V., LIEUT. "Nipsic."
WADSWORTH, HERBERT, ESQ., No. 45, Beacon St., Boston, Mass.
WAGGENER, J. R., P. A. SURG. "Vandalia."
WARD, A., MASTER. "Constitution."
WARING, H. S., MASTER. Arctic Relief Stmr. Helen and Mary.
WASHINGTON, R., PAY INSP. "Richmond,"
WATSON, E. W., LIEUT. Navy Yard, Norfolk.
WEAVER, W. D., C. ENGNR. "Yantic."
WEBB, T. E., NAVAL CONSTR. Navy Yard, New York.
WEEKS, J. W., C. MIDN. Naval Academy.
WELLS, C. H., COMMO. Navy Department.
WELLS, H., P. A. SURG. "Constitution."
WEST, C. H., LIEUT. "Alliance,"
WHITE, EDWIN, LIEUT. COMDR. Naval Academy.
WHITE, U. S. G., CIVIL ENGNR. Navy Yard, Boston.
WHITE, W. W., C. ENGNR. Naval Academy.
WILLIAMS, W. W., PAY INSP. "Trenton."
WILSON, D. L., MASTER. 53, Bridge St., Georgetown, D. C.
WILSON, J. C., LIEUT. "Tennessee."
WILSON, H. B., C. MIDN. Naval Academy.
WILSON, J. G., GEN. No. 15, E. 74th St., New York.
WINDSOR, W. A., P. A. ENGNR. Naval Academy.
WINN, J. K., LIEUT. COMDR. Key West, Fla.
WINSLOW, F., MASTER. "Saratoga."
WISE, F. M., LIEUT. "Despatch."
WOLFERSBERGER, W. H., C. MIDN. Princeton, Bureau Co., Ill.
WOOD, E. P., LIEUT. "Quinnebaug."
WOOD, T. N., 2D LIEUT., U. S. M. C. Marine Barracks, Washington.
WOODWARD, E. T., COMDR. "Yantic."
WOOLVERTON, T., SURGEON. Naval Hospital, Phila.
WORDEN, J. L., REAR-ADM. No. 1428, K. St., Washington.
WRIGHT, A. H., LIEUT. COMDR. 23, Jenning's Ave., Cleveland, O.
WRIGHT, R. K., MIDN. "Constitution."
WYMAN, R. H., REAR-ADM. "Tennessee."
YATES, I. I., LIEUT. Schenectady, N. Y.
YATES, A. R., COMDR. Portsmouth, N. H.
ZANE, A. V., P. A. ENGNR. Arctic Relief Steamer, Helen and Mary.

LIFE MEMBERS.—3.

HON. R. B. FORBES, Milton, Mass.
COMDR. A. D. BROWN, PRIZE ESSAYIST, 1879. Torpedo Station.
LIEUT. C. BELKNAP, PRIZE ESSAYIST, 1880. Naval Academy.

HONORARY MEMBERS,—6.

Arranged in order of election.

CHIEF JUSTICE C. P. DALY, No. 11, W. 29th St., New York.
PRESIDENT C. W. ELIOT, LLD., Harvard University, Cambridge.
CAPTAIN J. ERICSSON, 36 Beach Street, New York.
SUPERINTENDENT C. P. PATTERSON, LLD., U. S. Coast Survey.
HON. R. W. THOMPSON, Ex-Secretary of the Navy, Washington.
GEN. U. S. GRANT. New York City.

ASSOCIATE MEMBERS,—19.

ACKLAND, W. A. D., COMDR. R. N. H. B. M. S. Triumph, Pacific Station.
ARTHUR, W., CAPT. R. N., British Legation, Washington.
BAILEY, N. P. ESQ. 11 West Twenty-eighth Street, New York.
BATTEN, A. W. C. LIEUT. R. N. H. B. M. S. Triumph, Pacific Station.
BRENTON, R. O. B. C., LIEUT. R. N. " "
BOUTELLE, C. O., ASSISTANT COAST SURVEY. Norfolk, Va.
BROOKE, J. M. ESQ. Virginia Military Institute, Lexington, Va.
CHASE, LESLIE, ESQ. No. 30 Broad Street, New York.
FORSTER, E. J., DR. Charlestown, Mass.
HOFFMAN, J. W., ESQ. 259 South 17th Street, Philadelphia, Pa.
HUNT, W. P., ESQ. South Boston Iron Works.
LYON, HENRY, M. D. Charlestown, Mass.
METCALFE, H., CAPTAIN U. S. A. Frankford Arsenal, Philadelphia, Pa.
MILLER, H. W., ESQ. Morristown, N. J.
MYERS, T. B., ESQ. No. 4 West 34th Street, New York.
NORDHOFF, C., ESQ. Alpine, Bergen Co., N. J.
ROPES, J. C. ESQ., No. 53, Temple, St., Boston, Mass.
RUSSELL, A. H., 1ST LIEUT., U. S. A. Watertown Arsenal Mass.
SARGENT, C. S., PROF. Harvard University, Brookline, Mass.

CORRESPONDING SOCIETIES.

American Academy of Arts and Sciences, Boston, Mass.
American Geographical Society, No. 11, W. 29th St., New York.
American Institute of Mining Engineers, Easton, Pa.
American Society of Civil Engineers. No. 127, E. 23d St., New York.
American Society of Mechanical Engineers. No. 239, Broadway, New York.
Association Parisienne des Propriétaires d'Appareils à Vapeur. No. 56, Boulevard Haussman, Paris.
Franklin Institute, No. 15, S. 7th St., Phila., Pa.
Military Service Institution of the U. S. Governor's Island, New York.
Royal United Service Institution, Whitehall Yard, London.
Société des Ingénieurs Civils. No. 10, Cité Rougemont, Paris.

NECROLOGY.

Chief Engineer Harman Newell. Born in Pennsylvania. Appointed Third Assistant Engineer, Sept. 22, 1849. Office engineer-in-chief and coast survey duty, 1849–52. Promoted to Second Assistant Engineer, Feb. 26, 1851. April 17, 1852, detached and leave. Aug. 10, 1852, to the Saranac, home station. Promoted to First Assistant Engineer, May 21, 1853. June 15, 1853, detached, and to the Princeton, home station. July 25, 1854, detached and to engineer-in-chief's office. Arctic expedition for relief of Dr. Kane, under Lieut. Hartstene, 1855–56. Nov. 18, 1856, to superintend repairs on the Fulton. Sept. 4, 1857, to the Fulton, Paraguay expedition and Brazil station. Commissioned Chief Engineer April 23, 1859. May 7, 1859, detached and to office of engineer-in-chief. May 17, 1859, temporary duty at Philadelphia. Sept. 1, 1859, to the Wyoming. July 2, 1860, recommissioned. Aug. 21, 1860, to the Powhatan, Atlantic Blockading Squadron. July 25, 1862, to the New Ironsides. Jan. 20, 1864, detached, and May 13, 1864, member Board of Examiners. Aug. 7, 1865, to the Norfolk Yard. June 15, 1869, to the Lancaster as Fleet Engineer of the S. Atlantic Station. April 24, 1872, detached and on sick leave. Sept. 2, 1872, President of Board of Examiners. Nov., 1872, to the Philadelphia Yard. Mar. 20, 1877, to the Hartford as Fleet Engineer of the N. Atlantic Station. June 30, 1877, to superintend construction of machinery for the Quinnebaug. Oct. 22, 1878, to the Norfolk Yard. Died, Norfolk, Mar. 24, 1880.

Lieutenant Colonel James Hemphill Jones, U. S. M. C. Born in Delaware. Commissioned Second Lieutenant from Delaware, Mar. 3, 1847. Mar. 11, 1847, to marine barracks, Philadelphia. Apr. 20, 1847, to recruiting rendezvous, Philadelphia. May 23, 1847, to duty with army in Mexico. Aug. 4, 1847, two month's sick leave. Nov. 1847, to marine barracks, Philadelphia. Mar. 4, 1848, to duty with army in Mexico. Aug. 31, 1848, dropped from the rolls, by order from Navy Dept., Aug. 18, 1848, in accordance with the provisions of the Act of Mar. 2, 1847, increasing the Marine Corps, during the war. Re-commissioned Second Lieutenant, Mar. 3, 1849, with rank from Mar. 3, 1847, in accordance with the Act of Mar. 3, 1849, and ordered to the Raritan, home station. June 22, 1850, detached

and to the marine barracks, Philadelphia. Dec. 24, 1850, to the Saranac, home squadron. Aug. 4, 1851, detached and to the marine barracks, Philadelphia. Mar. 18, 1852, to the marine barracks, Washington. May 10, 1852, to the Princeton. Detached Dec., 1852. Feb. 24, 1853, to the Macedonian, East India squadron. Promoted to First Lieutenant, Sept. 1, 1853. July 8, 1854, transferred to the Powhatan. Feb. 18, 1856, detached and two month's leave. April 21, 1856, to the receiving ship Ohio, Boston. May 15, 1858, to the Macedonian, at Boston. Sept. 1, 1859, to the marine barracks, Philadelphia. Sept. 11, 1860, to the Richmond, Mediterranean squadron. Dec. 15, 1860, transferred to the Susquehanna. Promoted to Captain, May 24, 1861. June 11, 1861, detached and to the marine barracks, Washington. Co-operating with the army in Virginia, July 16–22, 1861; at battle of Bull Run. Sept. 23, 1861, to the Lancaster, Pacific squadron. June 6, 1863, detached and to the Washington Yard. Promoted to Lieutenant Colonel, June 10, 1864. July 20, 1864, to marine barracks, Portsmouth. Dec. 10, 1867, to marine barracks, Mare Island. July 70, 1871, to marine barracks, Boston. Died, Boston, April 17, 1880.

Commander Sullivan Dorr Ames. Born in Rhode Island, July 16, 1840. Appointed midshipman from Rhode Island, Sept. 22, 1856. Naval Academy, 1856–60. Graduated June 15, 1860, No. 8, in a class of twenty five members. June 15, 1860, to the Dacotah, China station. Sept. 19, 1861, warranted Master. May 13, 1862, detached and to the Naval Academy; orders revoked and retained on board the Dacotah, N. Atlantic squadron; engagement with battery at Sewall's Point, May 8, 1862. Commissioned Lieutenant, July 16, 1862. May 15, 1864, detached and to the Naval Academy, executive duty. April 3, 1865, to the Colorado, European station; transferred to the Kearsarge. July 25, 1866, commissioned Lieut. Commander. Aug. 8, 1866, detached, and Sept. 25, 1866, to the Resaca, Pacific station. Transferred to the Pensacola. June 26, 1869, detached. Oct. 16, 1869, Boston Yard, ordnance duty. Feb. 4, 1870, detached, and Mar. 18, 1870, to the Naval Academy, executive duty. May 1, 1873, detached and to the Wabash, European station, staff duty. Jan. 6, 1874, commissioned Commander. Feb. 5, 1875, detached and six month's leave. Nov. 20, 1875, Portsmouth Yard, inspector of ordnance. Aug. 1, 1876, detached. April 11, 1877, inspector, fifth Light House District. Aug. 2, 1877, transferred to Second District. Detached Oct. 1, 1880. Died, Nov. 22, 1880. Total sea service, ten years, eight months; shore duty, eleven years, three months; in service, twenty four years, two months.

ANNUAL REPORT OF THE SECRETARY.

Mr. President, and Members of the Institute:—

In accordance with the custom established, I believe, at the last annual meeting, I have the honor to submit the following report in regard to matters connected with the office I have held during the past year. As it is difficult to draw the line between the matters appertaining exclusively to the duties of secretary and those of the other members of the executive acting as such, I shall include other matters which have at times been brought to the notice of the executive committee, the secretary of the Institute being at the same time secretary of that committee.

At present there are four hundred and eighty one members of the Institute, an increase of ninety nine as compared with the number reported by the secretary at the last annual meeting. The appended table, giving the number of each class of membership, will perhaps succinctly show the increase.

	Members.	Associate Members.	Life Members.	Honorary Members.	Total.
Jan. 1880.	368	7	2	5	382
Jan. 1881.	454	19	2	6	481
Increase,	86	12	0	1	99

It will be seen that this increase is mainly among the regular members. This is partly due to the adoption during the year of an amendment allowing persons not connected with the Navy to become members upon the same footing as naval officers; previous to the adoption of that amendment, gentlemen in civil life could become connected with the Institute only by election as honorary or as associate members. And here I may say that the large increase in the associate membership is due to the election of gentlemen as such, prior to the adoption of the amendment; since that time but one or two have been elected. Excluding the number of civilian members who have been elected, it is evident from the number of officers who have joined, that the interest taken by the Service at large in the Institute not only has not died out, but that it is spreading. Upon this account, the result must be gratifying to all interested, and also because it justifies us in consider-

ing an income assured, sufficient to meet with due economy all necessary expenses.

Viewing the affairs of the Institute from this standpoint, I venture to recommend that application should be made at the next session of the Legislative Assembly of Maryland, for an act of incorporation. I do not intend here to advance any arguments in favor of my recommendation, but simply to suggest the matter in such a public manner as to invite discussion among the members.

As I have mentioned above, the grade of associate member as originally established allowed the election of persons in civil life, interested in the Institute. The necessity for this being done away with by the adoption of an amendment allowing the election of fifty members unconnected with the Navy, I would suggest that the grade be reserved for military and naval officers alone. And in this connection I would recommend the creation of a grade of Temporary Honorary Members, to be conferred upon distinguished foreign naval or military officers during their temporary residence in the United States.

According to the report of the secretary, Lieut. J. C. Soley, at the last annual meeting, eight essays in competition for the annual prize given by the Institute, upon the subject, "The Naval Policy of the United States," were sent by him, in Jan., 1880, to Hon. Wm. M. Evarts, Secretary of State, Hon. R. W. Thompson, Secretary of Navy, and Hon. J. R. McPherson, U. S. Senator from New Jersey. Since that time nothing has been heard from these gentlemen, selected as judges by the executive committee, as to their decision.

The subject selected for the essays, for the annual prize of 1881, was "The Type of (1) Cruiser, (2) Armored Vessel, best suited to the present uses of the United States." In competition four essays were received and by me sent to the judges selected by the Executive Committee; viz., Commo. Wm. M. Jeffers, Chief Bureau Ordnance, Chief Engnr. J. W. King, and Chief Constructor John Lenthall. I regret to announce so few competitors for the prize when the question was one which afforded such ample field for discussion, but, possibly the paucity of the number of competitors may be attributed to the non-publication of the prize essay for 1880, and the consequent feeling of uncertainty generated in the minds of the members of the Institute.

During the year sixteen papers have been read before the Institute and the various branches; of these, eight have been published together with five articles not read but inserted under the head of professional notes, and one discussion upon a uniform system of Boat Rig, form-

ing Nos. 11, 12 and 13 of the Proceedings. Correspondence has been established with four additional scientific societies, and in addition, copies of the Proceedings have been sent to the leading professional periodicals of Europe. To a certain extent, American naval officers will be judged among the recipients of these numbers by the character and tone of the articles appearing therein. It has therefore been the aim of the Executive Committee to maintain a high standard by the character of the articles published and in other ways to attain the objects for which the Institute was established. Naturally of primary importance, in a publication of this kind, are papers containing original ideas upon matters pertaining to the naval profession. But further, papers not essentially original, but written for the purpose of disseminating scientific information are especially valuable. And again, perhaps no more fitting place could be found for monographs on Naval Biography and Naval History than in a journal written and maintained by naval officers. In fine, it is the desire of the executive committee to make the proceedings of the Naval Institute, a complete record of the workings of the naval mind for the years in which it is published, and to this end, it to be hoped that they will have the active aid and coöperation of their brother officers, without which success is impossible.

Respectfully,

C. BELKNAP,

Lieut. U. S. N. and Secretary.

Annapolis, Maryland, Jan. 13, 1881.

ANNUAL REPORT OF THE TREASURER.

U. S. Naval Academy.
Annapolis, Jan'y 7th, 1881.

Gentlemen:

The enclosed report is respectfully submitted of the receipts and expenditures of the Institute from Jan. 7th, 1880, to Jan. 7th, 1881, showing a balance on hand at this date of $ 601. 04; of this amount, there will be required $ 150.00 for the prize and medal to be awarded to the writer of the successful paper on the "Naval Policy of the U. S."; and about $ 190.00 for printing the last number of the Proceedings for 1880, (which is now in the hands of the printer) which will leave a balance of about $ 261. 00 in the hands of the Treasurer, after the settlement of all accounts belonging to 1880.

There is due the Institute from one hundred and three members who have not yet paid their dues for 1880, $ 309.00.

Respectfully,
JAMES P. SPRAGUE,
Treasurer U. S. N. I.

Amounts Received

by the Treasurer of U. S. Naval Institute from Jan'y 7th, 1880 to Jan'y 7th, 1881.

Bal. on hand, Jan'y 7th 1880,	$ 525 70
Dues received from various Branches,	410 76
" " at Annapolis,	783 00
Amount " for Advertisements,	48 00
" " " Life Commo. Morris,	76 00
" " " Proceedings,	11 75
	$ 1855 21

Amounts Expended.

Bills paid for Printing Committee,	$ 1048 62
Postage paid on Proceedings, and for officers of Institute,	69 14
Paper, Envelopes and Blank Books,	42 00
Expenses of the various Branches,	67 67
Freight and expressage,	26 74
	$ 1254 17
Cash in hands of Treasurer to balance,	601 04
	$ 1855 21

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. VII. 1881. No. 15.

NAVAL INSTITUTE, ANNAPOLIS, MD.,

DECEMBER 10, 1880.

Lieut.-Com'dr P. F. HARRINGTON, U. S. N., in the chair.

DEFLECTING ARMOR,*

By P. A. ENG. N. B. CLARK, U. S. N.

The construction of war ships has within the last forty years undergone many changes; among these have been the abandonment of sails as a sole means of propulsion, and the substitution of steam as the chief motive power, the application of armor as a means of defense, and the change from wood to iron as the material of construction. During the era of sails the vessels of our navy were unexcelled for speed, handiness of movement, gracefulness of form, and for all the qualities attainable by vessels propelled by means of sails. The advent of steam found the art of building sailing vessels in a highly advanced state; the materiel of our navy was probably at that time more effective, in proportion to its size, than that of any other country. In the introduction of steam our government took a leading part, so that at the outbreak of the civil war we had a fair proportion of steam vessels, as compared with other nations; but, unfortunately, a large part of them were of too great draught for the service then required. The large screw frigates of the Wabash class, the large side-wheel steamers of the Susquehanna class, and the sloops of the Hartford and Iroquois classes, were all of too great draught to render the most efficient service. The larger vessels

* The publication of this paper was delayed by request of the author.

could only enter one harbor south of Fortress Monroe, that of Port Royal, where two of them, the Wabash and Susquehanna, assisted by some other lighter vessels, mostly improvised from the merchant service, proved the efficiency of steam vessels, armed with shell guns, against land batteries, when there was sufficient water to permit them to come to close quarters, and keep under way at the same time. If, at the outbreak of the rebellion, the government had been in possession of fifteen or twenty ships of the double-ender or twin screw classes of vessels, of one thousand, or twelve hundred tons displacement, drawing not more than eleven or twelve feet of water, and armed with the shell guns with which Farragut won his victories, it is more than probable that the duration of the war might have been much contracted, for the ports through which supplies were afterwards introduced could at that time have been easily captured. The shoal water of the southern harbors more effectively defended them than the batteries they contained, for wherever the depth of water permitted us to bring our shell guns to bear at close quarters, the enemy were speedily put to flight. Therefore light draught is one of the first essentials for vessels intended to defend our own coast, or to operate against a foreign country.

Defensive armor for war vessels was first brought into practical use, in modern times, by the French during the Crimean war, in an attack on the Russian forts at Kinburn, October 17, 1855, where three floating batteries, armored with four and one half inches iron plates were brought into action; one of them, the Devastation, was said to have been struck sixty-seven times with shot, with no other result than to indent the armor at the most one and a half inches, but ten men were killed and wounded by projectiles which entered the ports. Previous to this period guns had been made, not to obtain great penetration, but rather to throw large projectiles at a low velocity, producing a smashing effect, detaching great quantities of splinters from the wooden sides, and spreading death and destruction in their flight. High velocity, which implies great penetration, was not desired, as such projectiles cut clear holes through wooden vessels, and detached far less splinters then those endued with less energy. The range of these shell guns was then sufficient for the purposes of combat between ship and ship: for it would be very difficult to strike an object from an unstable platform beyond their effective range; therefore long range guns were not made. The French laid the keel of La Gloire, the first sea going iron-clad, in 1858; in this vessel the entire

hull was enveloped in defensive armor of four and one half inches thickness; the British followed with the Warrior, armored with the same thickness of iron, but, owing to the greater length of the vessel, the armor was confined to the central part of the ship. The La Gloire constructed with a wooden hull has long since gone to decay, while the iron hull of the Warrior with no other repairs than those necessary for her preservation, such as painting and scraping, is apparently as sound to-day as when she was launched, showing the superiority of iron over wood for the construction of ships.

Neither the La Gloire nor the Warrior were launched until 1862, when Ericsson's Monitor astonished the world by her memorable conflict with the Merrimac; presenting the novel sight of two vessels armed with the heaviest naval ordnance of the day, discharging their projectiles at each other, for a considerable period of time, at very close quarters, without either being able to do the other any serious injury. In the construction of the Monitor her designer probably put vertical armor at once into the best form it is possible to put it for a coast defense vessel; improvements have been made in matters of minor detail, but the general form of the type is identical with the original.

Against the ordnance of the period, vertical armor as applied in the monitors was an efficient protection, and it was seen that guns of greater penetrating power than those then in existence were necessary to pierce it; that the short shell guns of large calibre, throwing projectiles at a low velocity, although admirably adapted for conflicts between wooden ships, were not suited for this purpose, but that guns of increased length in proportion to their calibre, enabling them to burn a larger quantity of powder, and throwing elongated projectiles at a high velocity, thereby concentrating a great amount of energy to overcome the resistance of a small area of armor, was what was required. Accordingly such guns were made, and the vertical armor was readily penetrated; the armor was thickened, but guns were made which pierced it.

The conflict between guns and armor has gone on for nearly twenty years, with almost unvarying success on the part of the guns; until, with the limit of power by no means attained, guns are now made capable of piercing three feet of iron armor. The weight of armor now easily penetrable is so great that even if the attempt to protect with it is confined to special parts, none but the largest vessels can carry it. In this state of affairs a resort has been had to iron plates faced

with steel, and to plates of pure steel, by which the thickness required has been somewhat reduced, but even with compound and steel armor the ascendancy of the guns is complete, when the armor is arranged vertically. As we have the same materials, iron and steel, out of which to make both guns and armor, it may be well to inquire why the victory has always been on the side of the guns? The answer is, we have endued our guns with a very large time element, while this most important factor is almost entirely wanting in vertical armor.

In speaking of the time element in relation to armor and guns, we should remember that in physics no period of time is so minute that it may not be still further divided; measured by the impression on our imperfect senses, the times of explosion of nitro-glycerine and gunpowder are of equal duration, but measured by their respective effects, we know there is a great difference, and that the time occupied in the combustion of gunpowder is of considerable duration when compared with the time of explosion of nitro-glycerine.

Gunpowder is a mere mechanical mixture in which the chemical equivalents are heterogeneously mixed and have to be changed from the solid to the gaseous state by heat before they acquire the mobility to seek their affinities; its combustion is progressive, one part combining and heating the other to the gaseous state that it may likewise combine; but all taking place in a period of time too minute to be appreciated by our senses. It is this element of time in the combustion of gunpowder that gives it its great value as a propelling agent. In nitro-glycerine, the explosive action is entirely different; as it is a chemical combination in which the molecules are systematically arranged side by side with their affinities, with the distance between them infinitely minute, ready to clash together instantaneously, with terrific energy, on the first vibration, all combining at once. In the explosion of gunpowder the combination of the elements is gradual and progressive, producing a propelling action by means of an elastic pressure; while the combination of the elements of nitro-glycerine is instantaneous, producing an impactive blow.

If we should charge our guns with nitro-glycerine we would shatter them to fragments, as well as the projectiles themselves. These would acquire but little power, as the explosion is so sudden that no time is given the shots to accumulate energy, before the guns are ruptured; but gunpowder, in a comparative sense, burns gradually and progressively, imparting increments of energy to projectiles the whole distance travelled from the breech to the muzzle of the gun. Immense energy is

imparted to projectiles without injury to the gun, by propelling them from the breech to the muzzle thereof by means of an elastic gas at as high a pressure as the gun will bear without rupture; the energy is imparted gradually, being accumulated from strains upon successive sections of the length of the gun, and stored in the shot during the time it is traversing that distance.

When we fire a shot against a vertical armor plate, we attempt to resist this immense energy upon the sharply defined area of the shot instantaneously; or during the time the shot at its high velocity is traversing the almost inappreciable distance iron will stretch before breaking. This time is infinitesimal, and the action of shot against vertical armor is in its time element analogous to the impactive explosion of nitro-glycerine. If we cannot use nitro-glycerine to impart energy to projectiles on account of its lack of a time element, we should not attempt to resist the enormous energy imparted to projectiles, through the time element of slow burning gunpowder, by the impactive resistance of vertical armor. By firing a shot against a vertical armor-plate we can readily pierce a thickness of armor much greater than the sides of the gun from which the shot was fired.

If, for the sake of theoretical illustration, we take two guns alike, and fit in the muzzle of one a piston, gas tight, and confining a high pressure of an elastic gas, and if we load the other gun with a charge of powder and a shot, and fire the shot directly against the piston, the energy of the shot would be gradually absorbed during its passage down the bore; the pressure of the gas increasing before it inversely as the space occupied—according to the well known law of Marriotte—until it is brought gradually to rest and shot out again, without injury to the gun fired into: all taking place in a period of time inappreciable to our senses, but of considerable duration when compared to the period of impact of shot against vertical armor. The operation is simply reversing the conditions under which energy was originally imparted to the shot; and no greater strain would probably be put on the gun fired into, than on the gun from which the shot was fired.

If we present a rigid, unyielding resistance to projectiles we invite destruction to our armor; if we present a yielding, elastic resistance we absorb the energy of the shot gradually, without injury to the armor, in like manner as it was imparted to it without injury to the gun. If a blacksmith were to use an anvil of very light weight, mounted on springs, his impactive blows would produce but little effect.

While serving on the Mississippi river, under Admiral Farragut,

during the civil war, the writer observed that shot fired from the bluffs, striking the decks of our vessels, were turned from their course by the most trifling obstacles, and passed on with apparently undiminished energy; at an acute angle the wooden deck itself was sufficient to deflect shot, while great resistance often failed to arrest them by direct impact. This led to the observation of the ricochet shot, which is simply a shot oscillating between two opposing forces, the upward deflecting action of the water's surface and the downward draw of gravity; such a shot on a smooth sea will travel for miles, performing many deflections; the initial energy being absorbed by the resistance of the air, the deflections, and the final plunge. From the great distance travelled, and the great number of deflections, we may form some idea of the small resistance required to deflect shot, as compared with that necessary to arrest them by direct impact.

That a gentle current of air blowing against the side of a shot will swerve it from its course, is a fact well known to all riflemen; in this case the shot is not deflected by encountering a resistance at its forward end, but the lateral divergence from a direct line is caused by the pressure of the air against its side; the curve described being the resultant of the initial energy of the shot and the lateral pressure of the air; showing how slight a force will swerve a shot from its course, when it acts through a comparatively great period of time; or, what is the same thing, while the shot is traversing a comparatively great distance.

In the Peruvian ram Huascar the armor of the turrets consisted of iron five and one half inches thick, except around the ports, where it was seven inches in thickness, backed by fourteen inches of teak; the side armor consisted of four and one half inches of iron, backed by fourteen inches of teak. The guns used against her were comparatively light. All shot striking near right angles to the armor's surface pierced it; all striking at an acute angle glanced off, merely indenting the armor. The armor was arranged to resist shot by direct impact but the only protection obtained was by deflection.

The conclusions are:—

1st, Projectiles from modern guns can pierce the thickest armor a ship can carry, provided they strike at nearly right angles to its surface.

2nd, Shot striking armor at an acute angle glance harmlessly off, merely indenting the armor.

3d, The more acute the angle of impingement, the less thickness of armor required to deflect the shot.

4th, Armor is at present arranged vertically to arrest or resist shot by direct impact, while the only protection obtained is by deflection.

5th, It is therefore proposed to arrange the armor at an acute angle, to deflect the shot from first intention, and make no attempt to resist the irresistible.

In disposing armor to deflect shot great attention should be paid to its elasticity—which simply means a time element—for the more gradually the direction of the shot is changed, by creating an elastic resistance under them, the less injury the armor will receive.

Elongated projectiles attain their great penetration by concentrating the energy due their great weight and velocity upon the area of their cross section. By deflecting armor the ends of such shot can be easily turned, so as to present the much greater longitudinal section to the armor, which will greatly facilitate deflection. When a shot strikes a deflecting surface it makes a spoon shaped dent, the length of which indicates a part of the time element of the armor; but as the armor is elastic, and yields bodily to the shot, another increment of time is added.

By the use of comparatively light plates of a good quality of low steel, disposed at an acute angle, we distribute the impact of the shot over a larger surface of armor, gain the mechanical effect of the inclined plane, infuse a further element of time by means of an elastic resistance under the shot, thereby deflecting them from the armor's surface, after absorbing only the small portion of energy necessary to turn them slightly from their course; permitting them to pass on and expend their remaining energy elsewhere.

While the action of projectiles against vertical armor is analogous in their time element to the impactive explosion of nitro-glycerine, their action against the acute deflecting armor described will be analogous to the more gradual explosion of gun powder, and, with it, as we have the same materials out of which to make both armor and guns, armor can be made equal in resistance to the power of guns, as the armor absorbs but a portion of the energy with which projectiles are endued.

The application of the principle of deflection as a means of defense is probably coëval with primitive man. The shields of many tribes of savage people of the present day are made of a curved form, that the weapons of an enemy may glance from their surfaces; the shields of the ancient Roman soldiers were of a similar form; so that an adversary's battle-axe would glance from them, and before it could be raised again the short sword from behind the shield had done its work.

The application of the principle of deflection to resist naval ordnance is by no means new; an American inventor, Thomas Gregg, obtained a patent for an armor-plated vessel, with inclined sides, as early as 1814; this shows a far better appreciation of the requirements of a vessel to resist ordnance than any of the recent constructions of the great naval powers of Europe. The Confederates made use of the principle in all their armored vessels; as did likewise our government in many of the gun-boats built for service on the Mississippi, and other western rivers. But, in all these constructions the entire hull was enveloped in defensive armor; a method which will not admit of angles of impingement sufficiently acute to resist modern ordnance, without reducing the margin of buoyancy to such a degree as would render the vessel liable to sink on the admission of a comparatively small amount of water.

In order to present angles of impingement sufficiently acute to deflect shot, stored with the immense energy imparted by modern guns, it is proposed to protect the water line by one device, and the guns by another above it, with a free and unobstructed passage for shot—so far as armor is concerned—between the two; as the less resistance offered, the less injury received.

The armor defending the water line is to consist of an Interior Convex Deflecting Shield, which is to be secured to the sides of the vessel four or five feet below the water line, and to extend across from side to side in the form of an arc of a circle, or some approximate curve; rising amidships some two or three feet above the water line, and dipping at the stem and stern some six feet, or more, below it. The position of this shield, as regards the water line, will vary with the size of the vessel, but it is to be of such a form, and to be so placed within the hull, as to present a practically constant angle of impingement to a horizontal shot at the water line, in all the positions the vessel may assume in rolling and pitching, and that so acute as to make penetration impossible with a very moderate thickness of armor. As the interior shield rises amidships considerably above the water line, it protects the vital far side of the vessel, where projectiles at their exit do the greatest damage.

In order to secure the buoyancy and stability of the vessel, it is proposed to pack the cellular sides above and below the shield with cotton chemically prepared to resist fire, which will by its elasticity close up shot holes as fast as made, and thereby prevent the entrance of water; and if the space between the convex surface of the shield

and the deck above it was divided into water-tight compartments, and packed with ship's stores, put up in metallic canisters of rectangular form, so as to stow closely, and to exclude water, the buoyancy and stability of the vessel would be still further insured. Or this space may be packed with cork or other buoyant substance, so that although the vessel above the interior shield is completely riddled by shot, her buoyancy and stability will remain intact.

Shot striking the side of an iron or steel vessel fitted with such an interior deflecting shield and with cotton packed sides would make a clear-cut hole at their entrance which would be immediately closed by the elastic cotton, and, impinging against the shield at an acute angle, this shot would be deflected upward and outward, far above the water line on the other side.

It is to the far side of a vessel that projectiles do the greatest damage; shot fired from a distance and striking a vessel near the water line would be carried considerably below it on the far side by the curve of their trajectory. Projectiles entering the side of a vessel above the water line are apt to be deflected downward, by encountering any obstacle, and make their exit below it on the other side.

The heavy percussion shell now in use, each one of which is in itself a mine, will do great damage to the far side of a vessel, where their exploding cones will doubtless blow out entire sections of plating, and admit great volumes of water; while solid shot striking the transverse frames will also be apt to displace entire plates from the far side below the water line. Against such missiles, the cellular system of construction alone, is entirely inadequate to give protection; but in combination with the interior deflecting shield, complete protection for the water line can be obtained, under all ordinary conditions; but no form of armor can protect a vessel from projectiles fired at very close range from guns depressed.

The deflecting action of the water's surface, and the fact that elongated projectiles fired from rifle guns at an elevation strike the water butt first and tumble end over end, will protect the near side of a vessel below the water line; while the far side would be most effectively protected by the interior deflecting shield described. The flat trajectory of the projectiles of modern guns will enable them to strike a target of a given vertical plane at a great distance, but a target of a horizontal plane at a like distance would be very difficult to strike; while curved fire from land batteries will be very effective in defending narrow channels against the passage of ships, where the range is

known, such fire would be a mere waste of ammunition if the guns were on the unstable platform of a ship rolling at sea, and directed against another vessel.

The cellular system of construction, in combination with an under water armored deck, situated a foot or two below the water line, with water excluding stores packed above it, will not give the same measure of protection as the interior shield rising considerably above the water line amidships, and thereby protecting the vital far side; for the heavy shell now in use would soon blow out the stores, as well as the side of the vessel confining them, and admit great volumes of water. This would heel the vessel over so that projectiles would strike the under surface of the armored deck, and be deflected downward through the bottom of the vessel, probably exploding as they went. A flat armored deck situated but a short distance below the water line, would be liable to receive shot under it as the ship rolled, and, instead of being a safeguard, would be a positive source of danger—to a vessel fitted with it—from the downward deflection of projectiles. With the ship's stores packed in the water-tight compartments above it, the interior shield practically takes up no more room than its air space, and is specially adapted to vessels of light draught, such as we require, as it rises considerably above the water line amidships; while the armored deck being entirely below the water line, would, in a light draught vessel, greatly encroach upon the space necessary for the boilers and machinery. The interior deflecting shield, with the cotton-packed sides, for closing shot-holes, and the water-tight compartments above it, stowed with ship's stores, put up in rectangular metallic canisters to pack closely and exclude water, form a combination of elements for the end in view which it would seem difficult to excel.

It is proposed to protect the guns, and the men to serve them, in deflecting turrets, or double convex gun shields, the surfaces of which present angles of impingement so acute as to deflect shot with comparatively light armor. These deflecting turrets may be supported above the interior deflecting shield in different ways. One plan, illustrated in fig. 1, is to make the deflecting turrets in two parts; the lower part is securely attached to the interior shield B, being supported above it on a stout central cylindrical column C, which should be made hollow to admit of the passage of men and ammunition from the magazine below the water line; as this column is very short, it can easily be made sufficiently stout to resist shot; besides its cylindrical form makes it an excellent deflector. The deflecting turret is

also supported on the concentric cylinders, D, D^1, D^2, D^3, made of sheet metal, which will render an efficient support but interpose no substantial resistance to the passage of projectiles through them; and therefore are not liable to be shot entirely away.

An intermediate deflecting plate X is placed between the two shields to prevent shot from being deflected from one shield against the other at a penetrating angle. The lower part of the deflecting turret is cut, and the upper part rests on the anti-friction wheels, F, F^1, F^2, F^3, Figs. 1 and 2, and revolves with its contents on circular tracks on the stationary lower part.

In view of the great length now given to guns to obtain the penetration required, it is proposed to protect the ends extending beyond the deflecting turrets with the auxiliary deflectors W W, Fig. 2, which are of convex cross section, made of very heavy sheet metal, and secured to the guns by means of bands. If one fourth the weight of metal used as armor to protect guns was put into the guns themselves in a deflecting form, the guns would need no other protection.

The space between the interior deflecting shield protecting the water line, and the deflecting turrets protecting the guns and the men to serve them, is to be as free and unobstructed for the passage of shot as an adequate support of the deflecting turrets and the requirements of a sea-going vessel will permit. As shot follow the direction of the least resistance, all the parts of the vessel contiguous to the deflecting surfaces should be made as light and penetrable as possible; so that projectiles are not bound up against the armor thereby penetrating it.

Figs. 3 and 4 illustrate the general plan of a vessel armored with the interior deflecting shield, for the protection of the water line, and double convex deflecting turrets, for the protection of the guns and the men to serve them. The deflecting turrets are here supported beneath the interior shield, each on a stout central column or spindle C; which is stepped in a large casting D, resting on the keelson of the vessel. The castings constitute hydraulic presses, and the spindles, plungers; upon these the turrets are supported on hydrostatic pressure, which admits of great facility of rotation. The deflecting turrets, supported above the interior deflecting shield on four stout cylindrical columns, a and b, which revolve with them, one immediately under each gun, and one at the breech of each gun, through which the ammunition is elevated from the magazine beneath the interior shield. When the guns are bearing on an enemy, the rear col-

umns are behind, and covered by the front ones, and as they are very stout, and of cylindrical form, they are excellent deflectors, and therefore could not be shot away.

The deflecting turrets may be supported above the interior shield upon one central cylindrical column, with an aperture through it sufficiently large to admit of the passage of ammunition and men. These supporting columns can easily be made sufficiently strong to resist shot, and it is probably the best form of support of the three described. Composition anti-friction wheels E, E, Fig. 4, set in the edges of the circular hatches through the interior shield give the deflecting turrets an efficient lateral support.

The interior shield presents a practically constant angle of impingement to horizontal shot in all the positions the vessel may assume in rolling and pitching; while the deflecting turrets will present a constantly varying angle as the ship rolls; when, however it is considered that the deflecting turrets deflect laterally as well as vertically, and that the varying angle is very small, except through the center of the turret, the danger of penetration by an increasing angle will be found not very great.

The armor, forming the interior shield, is constructed in two layers, plated diagonally to break joints, and secured together by means of taper rivets with counter-sunk heads. As great rigidity against shot is not desired, but, instead, a certain degree of elasticity, no framing will be required to support the interior shield, other than one central longitudinal, and the transverse bulkheads, necessary to divide the space under it into the desirable number of water-tight compartments.

The interior shield, extending the length of the vessel and beyond the bows to a ram, tied in by the chords of its arc, and supported on the longitudinal and transverse bulkheads, in combination with the ship's cellular bottom and sides, forms a ram and a vessel of unprecedented efficiency and strength. The weight of the interior shield is distributed over the vessel in almost direct ratio to the ability of the different parts to bear it, and therein differs advantageously from vertical armor, which throws great stress on special parts, and is a source of weakness to a vessel: while the interior shield is an element of immense strength, as it gives a rigidity to a ship which could not be better attained if the material was disposed for that purpose alone. A point which should not be lost sight of is the great efficiency of such a ship as a ram; when a vessel is struck which is moving across the bows with a high velocity, the wrenching effect is such as

few ships built as rams can sustain; but such a vessel as described possesses the strength in an eminent degree to resist such a transverse strain.

At all places where openings are made through the interior shield for hatches, smoke pipes, ventilators, etc., the armor should be brought up square, or level all around with the highest part of such opening, and where the angle has to be made more obtuse, the armor should be thickened, as compensation; and all such openings should be defended by heavy gratings. The armor around the large circular hatch Fig. 4 is squared with the crown of the shield, and thickened where the angle above the water line is made more obtuse; this gives the interior shield the appearance of having plane sides, which is owing to the section being made through the diameter of the hatch; at all other points the shield conforms to the arc of a circle, as shown by the dotted lines.

Elongated projectiles fired from rifled guns at an elevation maintain the elevation of the gun in their flight, as the longitudinal axis of the shot remains parallel to the axis of the bore of the gun from which it was fired. The curve of the trajectory is the resultant of two forces—the initial energy of the shot and gravitation; and the latter force acting on each end of the shot alike, it falls bodily; consequently, such shot would strike the interior shield in a position favorable to deflection, as shown by figure 5.

In order to guard deflecting armor against square headed punching shot, which might otherwise penetrate it, it is proposed, if found necessary, to cover its surface with a system of auxiliary sliding deflectors, made of light sheet metal, and slightly attached by screws, or tap bolts, the object being to ride projectiles on them up the convex surface of the armor. These sliding deflectors may be of several forms. In Fig. 6, they are represented as beveled on all four sides, so as to freely slide over each other; in Fig. 7, they are represented like shingles on a roof, only in reverse order; Fig. 8 illustrates sliding deflectors of the same general form as Figure 6, but dished, so as to stand off from the armor and leave an interstice. These sliding deflectors would be carried away by shot striking them; but, as it is proposed to have no man exposed during action outside the armor, no material damage would be done by the upward flight of the deflectors, or of projectiles deflected from the interior shield. The sliding deflectors represented by Fig. 8, which are dished, and stand off from the armor's surface, would act as stiff springs to projectiles

striking them, and would add to the elastic resistance under the shot. This would greatly facilitate deflection, by turning the point of the shot and bringing it sidewise against the armor, thereby greatly increasing the area presented. The more gradual the contact between shot and armor the less injury the armor will receive, for it is by the concentration of energy on a small surface that armor is pierced.

A shot striking one of the dished sliding deflectors, Fig. 8, the moments of time and augmenting resistance under it, may be divided into four. 1st, time gained and pressure augmented under the shot from the first contact until the under surface of the sliding deflector is pressed down against the armor. 2nd, time gained and pressure augmented under the shot while it is riding on the deflector up the convex surface of the armor. 3rd, time gained and pressure augmented under the shot while the armor is yielding locally to it. 4th, time gained and pressure augmented under the shot by the armor yielding bodily to it. These increments of time and resistance blend, and run into each other, and are too minute to be appreciated by our senses; but during the period, the center of gravity of the shot describes a curve which clears it of the armor's surface. The length of this curve, beginning at the point of first contact and ending where the shot flew off at a tangent, indicates the time element of the armor; this may be very short when compared with the length of the gun, but as equal increments of energy are not imparted to shot the whole length of the bore, the greater portion being imparted at the breech end, and as the shot still retains the greater part of its energy after it is deflected, it is evident that deflecting armor does not need a very great time element.

The British Admirality have made experiments with deflecting armor, with a view of ascertaining the least possible angle at which square-headed punching shot would bite, and have found that the best Whitworth and Palliser shot under the most favorable circumstances could not be made to bite at a less angle than eleven and one half degrees. The square-headed shot are very wild in their flight and therefore not likely to come into general use; but if they are used, the sliding deflectors will turn their ends and present their sides to the armor, thereby depriving them of their penetrating power.

In view of the deadly efficiency attained by modern machine guns, and, as in future naval warfare the gun ports will doubtless be the targets upon which these destructive engines will be directed, it has become desirable to pass the guns through the armor by the least pos-

sible opening. Therefore it is proposed to mount each gun between two beams, or girders I, I, Fig. 2, upon which they are to slide back and forth on four lugs L, L, made on the gun, or secured to it by bands, and extending through slots in the beams. The beams are joined together at the breech end of the gun, forming a frame which at the muzzle end is attached to the armor by the joints J, J, on a line with the passage of the gun through the armor; this admits of elevation, depression and recoil, through the smallest possible opening; so that when the gun is run out the armor fits closely around it.

The guns are to be elevated and depressed by means of the hydraulic presses K, K, the rear end of the frame being elevated and depressed with the gun, which has no trunnions, the joints J, J, serving instead. The recoil of the guns is to be received on the hydraulic recoil presses M, M, which also serve to run the gun out to fire, and both in and out, whilst exercising. Upon each gun frame there is an attachment extending out from the gun for the support of a radius bar, one end of which is attached to the frame, the other end being secured to the breech block of the gun; when the gun is run out, the radius bar pushes the breech block into the gun, ready to fire, and stands at right angles to the axis of the bore; when the gun is run in, the radius bar draws the breech block out of the gun ready to reload. The object of this arrangement is to draw the breech block out of the gun by means of the recoil. The guns as shown recoil 2 feet 3 inches, and the breech block does not commence to open until the gun has recoiled a foot. The Krupp breech block draws easily from the gun after it is started, and the radius bar will exert great power to start the block; if one of the eyes in the bar is made elliptical, so as to give a little play to the bolt, the bar would act with a jerk, which would prevent the block sticking fast.

The guns permit of elevation of ten degrees. The ammunition, which for convenience is assumed to be fixed, is to be elevated from the magazine, and pushed into the tilting pipe P, Fig. 4, where it is caught by spring catches, the elevator retiring down the tube. The pipe P is mounted on trunnions and swings upon a crane. The gunner then swings the charge by the crane to the rear of the gun, turns the pipe over into the horizontal position, as shown by the dotted lines, and by a thrust of the hydraulic rammer R, pushes the charge into the gun; the gun is then run out, and fired, the radius bar, actuated by the recoil, opening the breech for another charge, which has by this time been elevated and swung into position in the rear of the gun.

Deflecting turrets may be made in which the guns are mounted en barbette, with the hydraulic and loading gear protected inside. The guns are mounted in frames, jointed at their forward ends—similar to those previously described,—the frames forming a part of the top of the turret, into which the breech ends of the guns are set. This form of deflecting turret possesses the advantage of placing the weight of armor lower, thereby increasing the stability of the vessel. The guns are elevated and depressed by means of hydraulic presses inside the turret; and they slide back and forth on lugs, which in this case are under them; the recoil is received on a hydraulic press behind the forward lug, and under the gun. The same general form of loading apparatus and breech movement can be applied as described above, the guns being loaded by depressing the breech.

As the loading apparatus of all the deflecting turrets revolves with them, the operations of loading and firing can go on uninterruptedly without the necessity of turning to a loading station after each discharge, and then having to seek the target again; The loss of much valuable time, at a critical period, is by this arrangement avoided. With the loading apparatus and automatic breech movement described the guns can be loaded and fired with great rapidity; and while a heavy armor-clad is damaging the light upper works of a vessel protected with deflecting armor, the latter could with the appliances described, drive shot after shot in rapid succession through her opponent's vertical armor, and by the fragments displaced, transform her very means of defense into deadly missiles of destruction.

As to the material of which to construct the hulls of war vessels there can be no hesitation in regard to the choice, iron or low steel being the materials par excellence. Wood as a material of construction was abandoned by all European nations as early as 1871. In the merchant service high authorities assert that the saving in weight effected by the change from wood to iron is as great as thirty or forty per cent. At the present time no European nation constructs war vessels of wood, greater strength being attained with far less weight, by the use of iron, and the superiority does not consist in greater strength alone, but in far greater durability. The wooden vessels now in service require extensive repairs after each cruise, costing immense sums of money, and requiring considerable periods of time, during which the service of the ship is lost to the country. But it is not only the loss of the use of the vessel when needed, and the excessive cost of repairs which we incur by building them of

wood, but every vessel so built carries a useless weight of from thirty to forty per cent. of the weight of her hull, which might be applied to give her additional powers of offense, defense, and mobility.

One of the first requisites of a modern war ship is high speed, and for this the necessary rigidity of hull cannot be obtained if wood is the material used; nor can the cellular system of construction, that great safeguard of buoyancy and stability, be applied except in iron or steel vessels; besides the stowage capacity of such ships greatly exceeds that of wooden vessels. By the use of steel as the material of construction the same strength of hull can be obtained with one fifth less weight than if iron was the material used. Ex Engineer-in-Chief J. W. King, U. S. Navy, says in "The War Ships and Navies of the World," "Formerly the greater first cost, and the doubtful character of the metal produced, constituted serious objections. Now however the manufacturers have placed on the market steel specially adapted to ship-building—a metal so mild, as to bend rather than break, in case of severe strain, and yet possessing a higher tensile strength than wrought iron, and approximating iron in first cost. Such an access of ductility and tensile strength is secured by the use of this steel, that Lloyds allows a reduction of twenty per cent. in the thickness of plating and frames of steel vessels. The plates of this metal are much less likely to be weakened by punching closely spaced lines of rivet holes, and as they are equally strong crosswise and lengthwise, instead of having their strength like iron in the direction of the fibre only, they are obviously more to be depended on. The absence of lamination in steel plates, and their greater smoothness, are other advantages possessed by them over iron." Greater strength can be obtained with from thirty to forty per cent. less weight if iron is used to construct the hull than if wood is the material employed, and steel gives a further gain of twenty per cent. over iron; therefore steel should be the material chosen, but great care should be exercised in its selection. Iron and steel are capable of producing vessels—if built on the cellular system, of far greater buoyancy than wood; but no matter of what material a ship is constructed, she could not long be kept afloat when subjected to the fire of modern ordnance, if her water line is not protected with defensive armor. We hear much of the buoyant qualities of the old wooden frigates, but if they had contended against ordnance like that now in use, their buoyant qualities would not be so highly rated.

Recent experiments made by Herr Krupp at Meppen go to show that great penetration can be obtained by guns of comparatively small calibre. A gun weighing but 3.9 tons of 6 inch calibre, throwing a shot of 112 lbs. gave a total energy at the muzzle of 2,170 foot tons, and at 2,150 yards of 1,306 foot tons, which it is estimated at that distance would pierce twenty inches of armor. Experience has proved that in small arms the greatest efficiency is obtained by using the smallest calibre that will effect the purpose; by diminishing the size of the projectile the number which a man can carry is increased, and it is argued that the bullet of the United States standard rifle .45 inch calibre will kill a man just as effectually as one of much greater size. This being true of small arms, why will not the same rule apply to naval ordnance, the object of which is to pierce an enemy's armor? Great penetration is obtained by increasing the length of the gun—in proportion to its calibre—and the size of the powder chamber, by which a much greater quantity of powder is burned, and a higher velocity imparted to the projectile.

A gun of 10 inch calibre can be made, firing a shot of 500 lbs., which will pierce a far greater thickness of armor than any ship can carry; such being the case it would seem to be unwise to make guns of such enormous dimensions as is now being done by some of the European nations, throwing projectiles of a ton weight or more. All the penetration necessary can be obtained with much less calibre, and therefore it would seem to be good policy to restrict the size of guns to that calibre which will pierce the required thickness of armor, and to fire a greater number of shot from guns of less size.

Guns of such great size of bore are not desirable, from the fact that to attain equal strength, wlth smaller calibres, their proportions have to be greatly increased; besides smaller guns can be operated with much greater rapidity. For cruising vessels doubtless guns of 6 or 8 inch calibre, if made of sufficient length, and capacity of powder chamber will be found to give all the penetration necessary. In addition to heavy guns, for piercing armor, all vessels should be armed with heavy machine guns; the larger size discharging percussion shell of two inches or more in diameter, and capable at ordinary ranges of piercing the side of an unarmored vessel or even light vertical armor; these should be operated by vertical shafting, driven by steam power from beneath the interior shield. In large vessels four such guns, two large, and two small, could be mounted in one of the deflecting turrets; in the lighter vessels they could be mounted on V

shaped deflecting shields, and would be very efficient weapons against torpedo boats.

The deflecting armor proposed possesses the advantage of great cheapness and simplicity of construction over the massive vertical armor now in use; any ordinary rolling mill being able to furnish the comparatively light plating required, and the appliances of any common machine or boiler shop serving to fit them together. No enormously expensive plant of machinery is required to roll and bend the heavy plates, and then to plane their edges so as to fit together, as in the case with vertical armor.

For coast defence I would suggest an armored vessel with a length over all of two hundred and fifty three feet, breadth of beam fifty five feet, draught of water sixteen feet, displacement four thousand tons, grate surface three hundred and eighty square feet. This will give a speed of about twelve knots per hour, and the draught will be sufficiently light to enable the vessel to enter the principal harbors on our coast. Four twenty-two ton breech-loading guns would be carried in two of the deflecting turrets described. The turrets are arranged so that all four guns may be fired directly ahead, three directly astern, or all four broadside. Quarters for the officers and crew are provided for by two houses on deck.

The important part which heavy machine guns will take in future naval warfare, will doubtless curtail the usefulness of unarmored vessels. These guns can be made to throw almost continuous streams of small percussion shell capable of piercing the sides of unarmored ships, or even light vertical armor, at ordinary ranges, so that it will be impossible for life to exist above the water line, on board such vessels, many minutes after the opening of a combat. Such ordnance will make armor a necessity for the protection of the men serving the guns; in a like manner the immense power of the heavy guns, firing shell terrific in their effects, will necessitate the protection of the water line in order to keep the ship afloat. Heavy machine guns can be made effective against an unarmored vessel at any range at which the guns of such ship can be advantageously used against armor. Unarmored vessels can be built carrying powerful batteries, with engine power sufficient to make them superior in speed to armored vessels; but if their gunners can be annihilated, and all parts of the ship penetrated by machine gun fire at any range at which her battery can be effectively used against armor, of what use is such a vessel for fighting purposes? She would possess the speed to chase an enemy

down, but would not be able to fight with any chance of success after having done so. Commerce destroyers, to enact the role of the Alabama, need not be fighting ships, for swift vessels from the merchant service can readily be converted into men-of-war for such purposes.

Invulnerability by means of defensive armor, great offensive power in the form of a heavy battery, a high rate of speed by means of great engine power, and corresponding coal capacity, and ability to turn quickly, are four qualities of the highest importance to a war vessel; but it is impossible to combine all these in the highest degree in one ship. A high rate of speed is of the greatest importance to all vessels protected with deflecting armor, as it is vulnerable to plunging shot fired from guns depressed, in the same manner and to the same extent as other vessels; and in order to maintain her superiority the ship should be enabled by greater speed to choose her own position. The much less weight of armor required to give an equal measure of protection, permits of the engine power to give the speed required when contending against vessels armored on the vertical system. Ability to turn quickly to ram, or to avoid being rammed, is another important quality; this implies a vessel of considerable breadth in proportion to her length, and is incompatible with extreme high speed; but as all the important qualities cannot be combined in one ship, it would perhaps in a cruising vessel be advantageous to sacrifice handiness to speed, and to gain the necessary displacement to carry the required weight of armor and engine power by increased length. All vessels except those of the smallest size should be propelled by means of twin screws, which will enable them to be manœuvred with facility; the steering gear of all vessels should be operated by means of hydraulic power, and completely protected either by armor or water.

Invulnerability by means of defensive armor, and a high rate of speed by means of great engine power can only be attained in vessels of considerable size, and for cruising ships of the first class, six thousand tons displacement would not seem to be too great. Fig 3 represents such a vessel, the length of which is two hundred and eighty-eight feet, breadth of beam fifty-seven feet; draught of water twenty-three feet, grate surface four hundred and fifty square feet, horse power four thousand. With a moderate fineness of lines this should give a speed of fourteen knots per hour; but the draught of water might be reduced, and the necessary displacement obtained by increasing the

length, and sufficient power might be added to give a somewhat increased speed.

The system of deflecting armor is applicable to all classes of vessels, light cruisers as well as heavy, but though the former need not be so heavily armored as to interfere materially with their speed, it is assumed that the water line of all ships should be protected, as well as a portion at least of the battery. While the deflecting turrets would seem to be the best form of armor for protecting the gunners of the larger vessels, the guns of the lighter vessels could be mounted on V shaped revolving shields operated through the crown of the interior shield, which would give protection to the hydraulic gear and the men working the guns. These V shaped deflecting shields could be closed at the rear, so as to give protection from small-arm and machine-gun fire all around, but they would only give protection from heavy projectiles from the direction in which the guns were trained. The guns could be kept constantly trained on the enemy, however, and, as it is probable that combats will be much more frequent between single vessels than between a greater number, the shields would give a fair measure of protection with a minimum of weight. A class of swift cruisers could be built armored with a light interior shield placed rather low to secure an acute angle of impingement, and armed with a battery of light breech-loading guns of great length and large capacity of powder chamber, mounted on four or five V shaped shields, placed amidships, with the guns operated by hydraulic gear, and capable with the appliances described of discharging projectiles of moderate size in rapid succession able to pierce the thickest vertical armor. Such vessels if made of sufficient size could be engined with the power necessary to attain high speed, with which they could choose their own position in combat. Or the guns could be mounted on an open deck with a small deflecting shield secured to the breech of each gun sufficient to shelter the one man necessary to work the hydraulic gear and to fire from splinters and machine gun missiles. The guns could be trained by means of stout vertical shafts extending from beneath the interior shield, which would also serve as conduits for the hydraulic power to the recoil and elevating presses. These shields can be made very compact and strong, and of such form as will deflect shot coming from the direction in which the guns are trained and affording protection against all but the heaviest projectiles.

Besides the larger ships, a class of smaller vessels of not more than eight hundred or a thousand tons displacement, drawing not more than

ten feet of water, to be used as rams, could be armored with an interior shield, which would give them great strength to resist the transverse strain to which rams are liable. Such vessels armed with one large rifle, mounted on a V shaped shield, would make very efficient rams and gunboats for defending a great length of coast; their light draught would enable them to enter all ports, and to seek safety in shoal water, in event of being pursued by a more powerful adversary. The interior shield is specially adapted to these light draught vessels; and it qualities are best displayed in vessels of considerable breadth of beam, giving great steadiness of platform for the guns and great stability under sail. The latter quality may be increased by water ballast in the cellular bottom, which also serves to trim the shield for action.

To avoid foulness of bottom all large cruising ships should be sheathed in wood and copper, but for the smaller class of vessels the composite system of construction would seem to furnish the requisite strength and protection with less weight.

All vessels should be sparred sufficiently to keep the sea under sail alone; which is a very important consideration in view of a lack of coaling stations. In Fig. 3, the sail plan of the vessel is illustrated; the vessel is fitted with tripod masts, intended to be unshackled, and lowered on deck on going into action.

Every vessel should be fitted with a series of pipes leading from the different water-tight compartments to the engine room, where they should be connected to a large centrifugal pump, placed high up in the vessel, so that it would not cease working even if the compartment in which it was situated was partly filled with water; these pipes should also be connected with the circulating pump of the condenser, by means of which any compartment could be pumped out, unless the leak was of inordinate amount. Before going into action all the water-tight doors in the lower part of the compartments should be closed, and in order to communicate with the different compartments under the shield without admitting water from one to the other, there should be a gallery or trunk, of sufficient size to admit of the free passage of a man through it, extending the length of the vessel, immediately under the interior shield, on one side of the central longitudinal bulkhead, and communicating with the upper part of each water-tight compartment, by means of water-tight doors. This would enable each water-tight compartment to be entered for inspection without endangering the others; and if the compartments were made air-tight above, as well as water-tight below, and a pipe run into each from a compressing air

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FIG. 1.

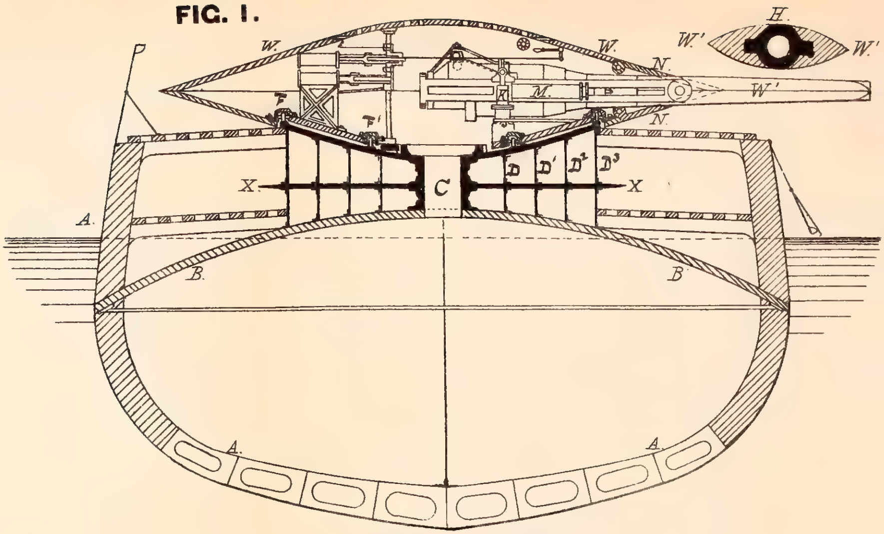
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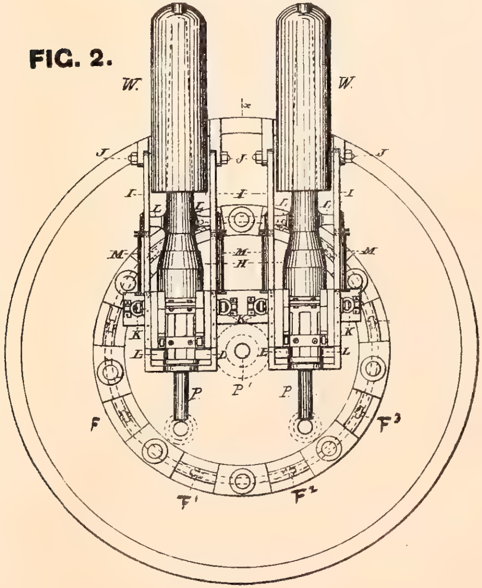
FIG. 2.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pump, any compartment found to be admitting more water than the pumps could free it of, could have air pressure forced into it, which would force the water down to the point of entrance. By this arrangement a vessel would be kept afloat which would otherwise sink, and it would permit of the stoppage of leaks, and the making of temporary repairs without docking the ship.

All large vessels should be provided with a pair of torpedo boats, to be used during action, which should be lowered and hoisted by steam power; steam power should also be applied to hoisting ashes, and to a steam capstan for working the anchors, and to raising and lowering the tripod masts.

The quarters for the officers and crew of war vessels is a matter of the greatest importance, for men to perform their duties properly should be in perfect health, and a high standard of health cannot be maintained when the officers and crew are crowded into the damp, contracted, ill-ventilated quarters which some of our war vessels present. The system of deflecting armor admits of the most commodious quarters, as all the space between decks in vessels constructed with a high freeboard can be utilized for this purpose, except that occupied by the deflecting turrets. As the accommodations will be entirely above the water line, they will be much dryer than those of vessels where they are partly submerged. The height above the water line will also permit each apartment to have a large port for the admission of light and air; the two most important factors of life and health.

In designing war ships these facts should be recognized;—that vertical armor has been tried, and found wanting; that the cause of its failure to afford protection is its lack of a time element equal to that of the guns used against it; that deflecting armor possesses a time element sufficient to resist the power of guns; that as it is only necessary to absorb a portion of the energy of shot to deflect them, and as we have the same material out of which to make both armor and guns, armor can be made equal in resistance to the power of the guns used against it by giving it an equal time element; that, in order to acquire the great penetrating power needed, guns have to be made of great length, which will require the adoption of the breech loading system; that the day has gone by when victories could be won by ships with their decks crowded with men tugging at the tackle of guns; that in working guns human muscle cannot compete with hydraulic power; that by the aid of hydraulic power one man can more effectively handle a gun, than any number could by the old method; that a

few guns of moderate calibre, capable of piercing vertical armor, with appliances for working them with great rapidity, with their hydraulic gear and gunners efficiently protected by deflecting armor, is a far more effective battery than one of slow working monster guns, firing ponderous projectiles of no greater penetrating power; and that a battery so protected will be more effective than a much larger battery of similar guns unprotected, or not so well protected; that with steel as the material of construction the same strength can be obtained with one half the weight of hull than if wood had been employed; that the stowage capacity of an iron or steel vessel is far greater than that of a wooden one; that the strength of hull necessary for high speed cannot be obtained with wood; that vessels to be used as rams require great transverse strength which cannot be obtained with wood; that the use of wood will not permit of the cellular system of construction; that constructed on the cellular system vessels of iron and steel can be given far more buoyancy and stability than those of wood; that the immense power of modern guns demands the protection of the water line of all vessels with defensive armor, and in like manner the great efficiency of heavy machine guns demands the protection of armor for the men working the battery and greatly curtails the usefulness of unarmored ships.

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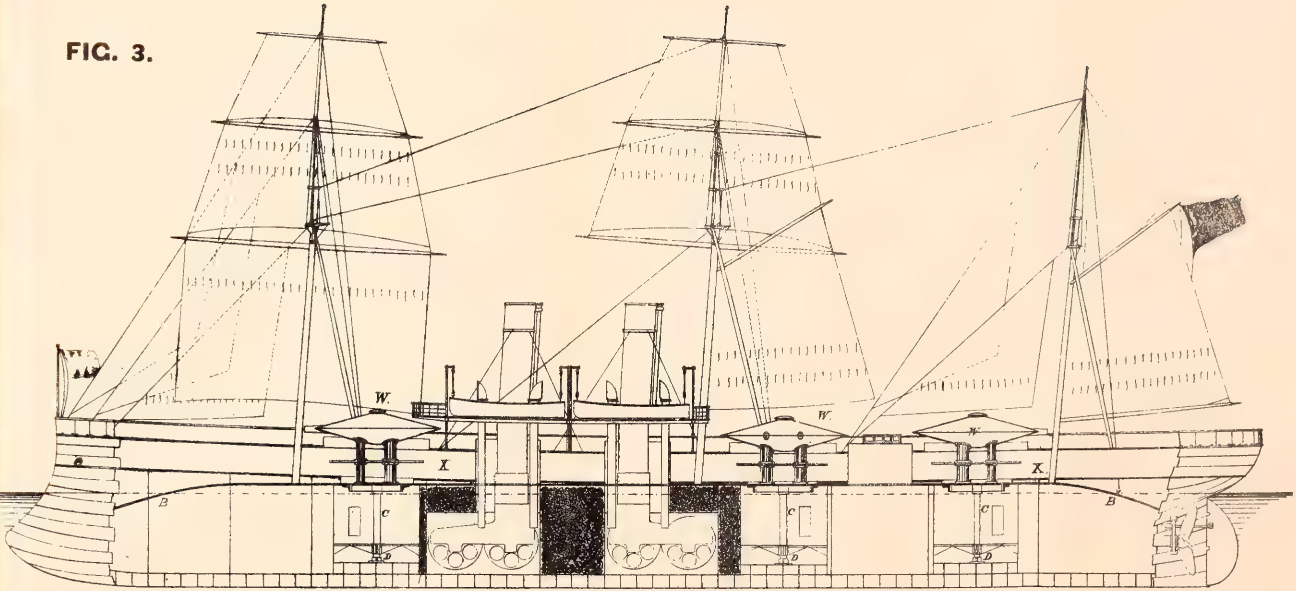
FIG. 3.



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NAVAL INSTITUTE ANNAPOLIS, MD.,

MARCH 12, 1881.

Lieut. G. W. TYLER, U. S. N., in the chair.

THE RECENT INVESTIGATIONS OF THE GULF STREAM BY THE U. S. COAST AND GEODETIC STEAMER BLAKE.

By Commander JOHN R. BARTLETT, U. S. N.

I consider it a great honor to be connected in any way with the investigation of this great river of the ocean, and it will give me pleasure to lay before the Naval Institute any new facts that I have obtained, under the direction of Mr. Patterson, the present Superintendent of the Coast and Geodetic Survey.

To the United States Coast Survey, first organized by Mr. Hassler, and especially to the systematic examination instituted by Professor Bache, are we indebted for most of our knowledge of the Gulf Stream, a knowledge which has been of inestimable value to the mariner. The investigations begun by Dr. Franklin, and pursued by his descendant Professor Bache, have been continued by Prof. Pierce and Mr. Patterson, but by none with more earnestness than by the present Superintendent, who has the advantage of the more modern and improved instruments. Mr. Patterson kindly gave me permission to use the data obtained by the steamer Blake, in preparing my paper. The Coast Survey deals only in facts, and the superintendent told me that any theories advanced, must be my own. I shall, however, present you the facts and leave you to draw the conclusions.

The facts obtained by the steamer Blake, regard : depths, temperatures from surface to bottom, character of bottom, specimens of water for analysis from surface to bottom, surface and under currents, and animal life from surface to bottom, especially at the latter.

Many of my hearers have probably read more than I on the subject of the Gulf Stream, and some have listened to papers by our

most learned and scientific men in relation to its origin, course, and temperature. A very interesting article appeared in the Galaxy from the pen of Dr. Hayes. Every one has read Lieutenant Maury's entertaining chapter on the Gulf Stream, in his "Physical Geography of the Sea"; but his theory of its source is generally disputed. He says the brine of the ocean is the lye of the earth, and that from it the sea derives dynamical power and its currents their main strength. He traces all ocean currents to differences in specific gravity.

It is its source of which I wish first to speak, in order to lead up to the point at which I hope to be able to give some new data. I will not enter into a lengthened discussion, but I wish to assume that the equatorial current is the source of the Gulf Stream, and I only quote a few words from the best authorities on the subject.

Sir John Herschel says: "The dynamics of the Gulf Stream have of late, in the work of Lieutenant Maury, been made the subject of much (we cannot but think misplaced) wonder, as if there could be any possible ground for doubting that it owes its origin entirely to the trade winds,"

Sir C. Wyville Thompson has some very interesting remarks on the Gulf Stream in his recent work, "The Depths of the Sea," and comes to the conclusion that it is the reflux of the great equatorial current.

Humboldt attributes the origin of this current to the trade winds, and lays the first impulse and origin of the Gulf Stream south of the Cape of Good Hope.

There is no doubt about the equatorial current. Columbus wrote in his journal: "I regard it as proved that the waters of the sea move from east to west as do the heavens." I would liken this great equatorial current to the heart in the human body, supplying the Gulf Stream with fluid as through the arteries, the water finding its way back naturally by the polar and colder currents or veins, to its original source. This action goes on in the Pacific as well as in our own Atlantic. The life or moving power is, as Herschel says, the trade winds, and this force is derived from the sun. Professor Bache, in his paper on the Gulf Stream, says: "The great part which the heat of the sun plays in disturbing the equilibrium of the surface of our globe is well understood. Wherever he shines upon the surface, the air resting upon it is set in motion, so that the circle of the sun's illumination, as it advances over the earth, is a circle of disturbance."

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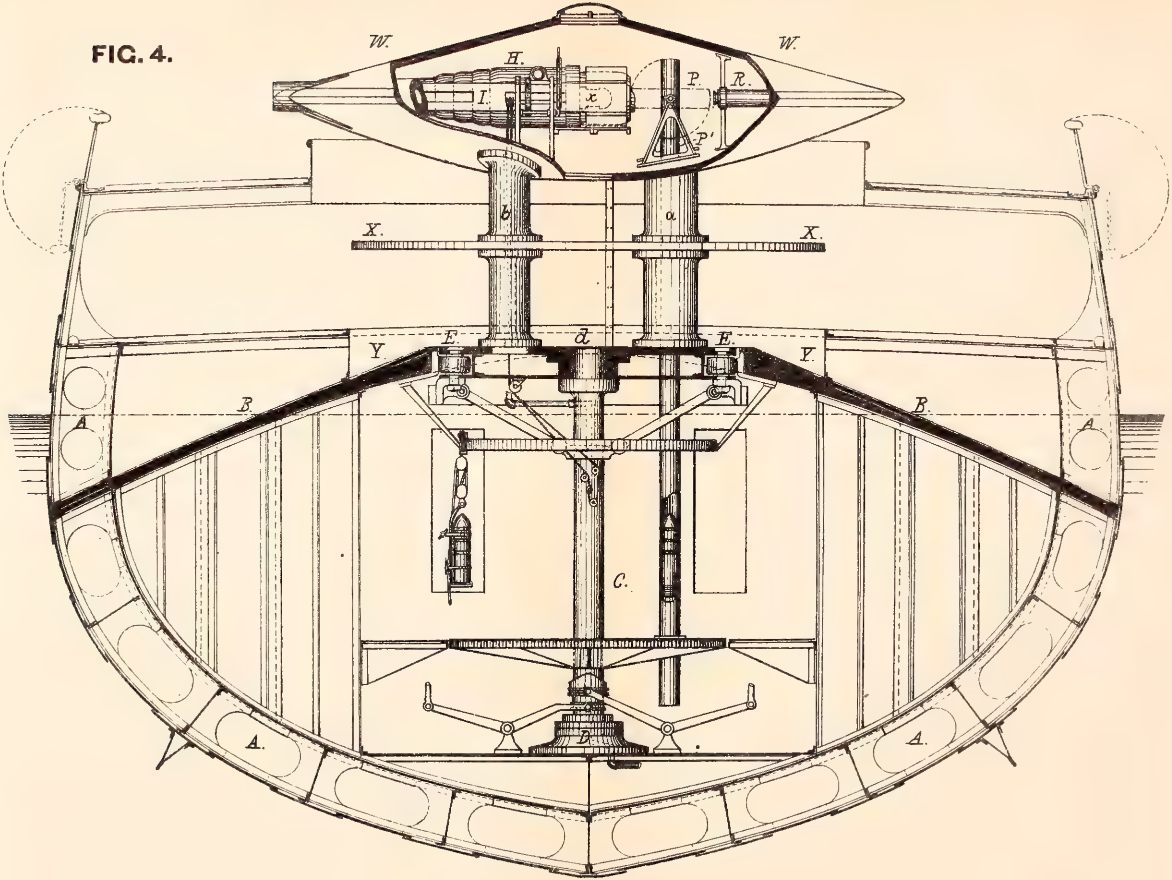

that volume of water moving from east to west on our globe, interruped by continents, and sending off branches in other directions, again to reunite, may be said to commence, or, more properly, reappear on the west coast of Africa. The action of the trade winds, which blow constantly between the tropics, is the cause of this current, and, without doubt, its velocity is increased by the rotation of the earth on its axis. Flowing on both sides of the equator in longitude 30° W., its breadth is estimated at 300 miles. Here it divides, the southern branch forming the Brazil current, the remainder flowing on to supply the Gulf Stream."

It is said to flow through the Caribbean sea to the Gulf of Mexico. It will be my purpose to show its course from the time we meet it to the eastward of the Windward Islands until it enters the Gulf of Mexico at the Yucatan passage. It is said that, at times, the water flows through this passage from 27 to 50 miles in 24 hours. Near Yucatan, we found it in the month of May flowing at the rate of three miles an hour. From this point the course of the current is generally described as making the tour of the Gulf of Mexico, or following around its boundary, before passing out at the straits of Florida. This is disputed now, with, I think, very good reason. The investigations made by the Coast Survey carry the current passing through the Yucatan passage well to the northward, were the waters are banked up by the pressure, and thus form a head or reservoir for the current, which flows from a point south of the mouth of the Mississippi direct to the straits of Florida.

South of Tortugas, the stream flows to the eastward, gradually increasing its velocity as it moves on. Opposite Havana, where its breadth is about 70 miles, its average rate is said to be two miles an hour in the centre, decreasing on each side ; northwest from Elbow Key, where its breadth is about 47 miles, the set, in the centre, is said to be northeast three miles an hour, with an increased rate toward the Florida reefs. The stream now bends to the northward, and, in the straits between Cape Florida and the Bemini Islands, its velocity is said to vary from one-half mile to even five miles an hour. This is the narrowest part of the stream, and I find it stated that its maximum temperature is 85°. The season of the year when it reaches this maximum is not given. I will speak of this part of the stream later on, and will mention the date when giving temperatures or currents observed by the Blake.

In November, 1878, I was ordered to report to the Secretary of the

Treasury for duty on the Coast and Geodetic Survey, and was assigned by Mr. Patterson, the superintendent of that service, to the command of the steamer Blake. My instructions for the first season's work, after the dredging for Mr. Agassiz had been completed, were as follows :

"You will please take soundings in the passages between all the islands from Trinidad to Cuba, not already sufficiently sounded, for the purpose of determining the ridge of least depth of water traversing these passages. Temperatures from surface to a depth of 100 fathoms, and at the bottom, should be obtained as often as opportunities offer, and serial temperatures, from surface to bottom, between the islands and on each side of the shoalest ridge."

It will be seen by these instructions that it was Mr. Patterson's idea to find the amount of water which enters the Caribbean sea between the Windward Islands, and, what was more important than anything else, to observe carefully the temperature of the water at different depths, as these temperatures would give the most interesting data in reference to the circulation.

As Mr. Patterson says in his report: "The discovery by the Challenger of submarine lakes whose temperatures are constant to the greatest depth with that of the ocean at the depth of their rims, rendered it more than ever imperative to determine the depth of the rims separating the waters of the Gulf of Mexico from those of the Caribbean, and its waters from those of the Atlantic, both to the eastward and westward."

As it was very important to connect the fauna of the West Indies with the Arctic fauna, and as naval officers are professionally neither naturalists nor geologists, Mr. Patterson sought the services of Mr. Alexander Agassiz, who consented to take charge of the special work, naming the localities to be dredged over, and taking care of the life obtained. Professor Agassiz joined the Blake with an assistant, and the first part of the season's work, until March 10, 1879, was occupied in dredging and trawling under the lee of the Windward Islands. We met with great success in this very interesting work ; but this part belongs more especially to Professor Agassiz, who will, in due time, present a popular account of the results of his labors. The working of the dredge and trawl was done by the officers and crew under my command.

Besides dredging under the lee of the islands, we made a number of soundings and hauls to the southward of Grenada, enough to develop the channel between that island and Trinidad. The greatest depth was

Treasury for duty on the Coast and Geodetic Survey, and was assigned by Mr. Patterson, the superintendent of that service, to the command of the steamer Blake. My instructions for the first season's work, after the dredging for Mr. Agassiz had been completed, were as follows :

"You will please take soundings in the passages between all the islands from Trinidad to Cuba, not already sufficiently sounded, for the purpose of determining the ridge of least depth of water traversing these passages. Temperatures from surface to a depth of 100 fathoms, and at the bottom, should be obtained as often as opportunities offer, and serial temperatures, from surface to bottom, between the islands and on each side of the shoalest ridge."

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FIG. 5.

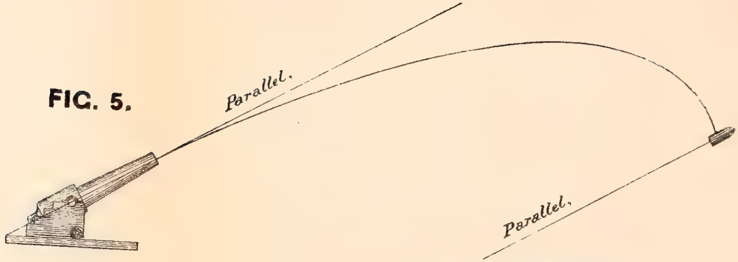


FIG. 6.

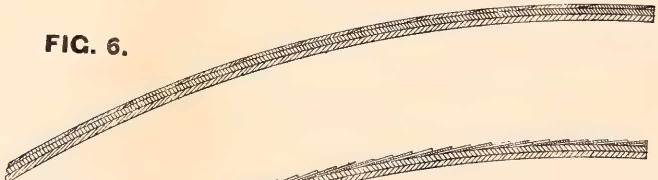


FIG. 7.

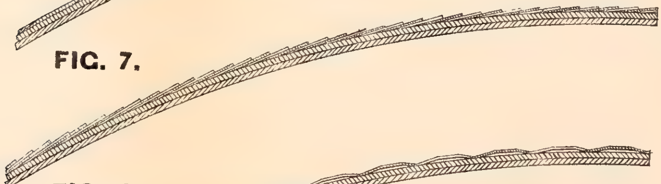
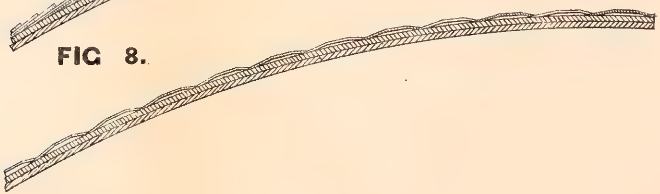


FIG 8.



421 fathoms in a channel 30 miles wide; temperature at bottom, 41½°* We were here the latter part of February, and found the current very strong to the westward. It is stated by a number of authorities, and published as the observation of the English surveyors, that a strong current is felt all along the Spanish Main a few miles from the coast.

In making the passage from St. Vincent to Barbadoes in the first week in March, we experienced a current of about 40 miles in 24 hours setting to the northward, and from inquiry on board English men-of-war and merchant vessels at that time in port, I found they had experienced the same northerly current. I crossed this passage again, in the latter part of March and in the middle of April, finding the same current.

Our method of finding the ridge connecting any two islands was by running traverses, or a line of soundings, begun in deep water and carried at right angles to a line drawn between the islands. The soundings would gradually shoal to a minimum and then increase, when a new line of soundings was run across the ridge at such an angle as to bring the soundings at the shoalest point about four or five miles apart. At every sounding the temperature of the surface was observed, as well as that of the bottom. I have spoken of the passage to the southward of Grenada. Our first sounding and temperature work was between St. Vincent and St. Lucia. A connecting ridge was found between these islands having a greatest depth of 488 fathoms, a bottom temperature of 41½°. The soundings across were 488, 370, 198, 171, 129, 164 fathoms.

It will be seen by the contour lines that the water deepened gradually to the Atlantic and quite abruptly into the Caribbean sea. Traverses were run between all the islands as far as the Virgin islands, with the following depths; Between St. Lucia and Martinique, 548 fathoms, temperature 41°; between Martinique and Dominica, 575 fathoms, temperature 41°; between Dominica and Guadaloupe, 346 fathoms, temperature 44½°; between Guadaloupe, Antigua and Nevis, 386 fathoms, temperature 45°; between Anguilla, Sombrero and Anegada, 1,100 fathoms, temperature 38° on the ridge, but this latter sounding was in a canyon, not more than two miles wide, and on each side of it were only a few hundred fathoms. Between Anegada and Sombrero, we found outside of the ridge, a temperature of 38° at 1,346 fathoms, 37½° at 1,643 fathoms, and 36½° at 2,558 fathoms. The low-

* All temperatures are given in degrees Fahrenheit.

est temperature that was found inside was between St. Thomas and St. Croix, that of 38° in 2,470 fathoms. To the southward of St. Croix, inside of the islands, the temperature of all depths below 800 fathoms was 39° to 39½°, and it was only in the deep hole north of St. Croix that we found anything lower. It will be seen by the contour lines that the deep water was traced in a channel from Anegada passage to a line between St. Thomas and the west end of St. Croix. The temperature at 1,542, 1,517, and 1,508 fathoms, south of Mona passage, was only 39½°, which would seem to indicate a connecting rim from St. Croix to the northward, cutting off the cold water that was found between St. Thomas and St. Croix.

In every passage a series of temperatures, or serial, was taken to the eastward of the ridge, then directly on the ridge, and again in the Caribbean sea. The depths for a serial were: surface 2, 10, 25, 50, 75, 100, 150, 200, 300, and so on at each hundred fathoms. The temperature at the bottom for the same depth remained constant in the same locality; by comparison, these agreed with the same depth obtained in a serial. At Barbadoes, St. Lucia, and Martinique the temperatures were at 100 fathoms 56½°; 200 fms., 51°; 300 fms., 45°; 400 fms., 43°; 500 fms., 41½°; 600 fms., 40½°; 700 fms., 40°; 800 fms., 39½°.

Just north of Guadaloupe the temperatures suddenly increased, and at Montserrat were: 100 fms., 67°; 200 fms., 57°; 300 fms., 48°; 400 fms., 45°; 500 fms., 42°; 600 fms., 41°; 700 fms., 40°. There was a slight increase as we neared the Anegada passage. These temperatures remained the same to the Mona and Windward passages, and were carried through the Western Caribbean. The temperatures in the Windward passage in May were: 100 fms., 68°; 200 fms., 61°; 300 fms., 53°; 400 fms., 47°; 500 fms., 43°; 600 fms., 41°; 700 fms., 40°; 800 fms., 39½°. The temperatures between Haiti and Jamaica were not quite as high. In February, the surface was several degrees lower than in May, but the temperatures at 100, 200, and 300 fathoms were the same, at the Windward passage.

Between some of the islands we were five and six days in completing the development of the ridge. The trades blew almost a gale during the months of January, February, and March, hence it was very tedious work, the small vessel of only 320 tons pitching her bows under, while the greatest care had to be exercised by the officer in charge of the sounding to prevent an accident to the wire. We worked during daylight, locating the position of the soundings by bearings taken on points of the islands, at night heading to the wind and sea under just

enough way to keep in our place. While at work among these islands I wrote to Mr. Patterson: "The water does not set into the Caribbean sea through the passages between the islands to any great extent. The trades bank the water against the windward side of the islands, and near their ends the current sets strong to the westward, but we did not find the strong current in mid channel."

In the passages between the Windward islands we saw large quantities of the sea or gulf-weed. In the latter part of April we had calm weather north of Guadaloupe, and I have seen this weed extend for miles in lines always pointing north. This was not owing to the wind, for at the time I speak of it was a dead calm, but seemed to be caused by the current flowing between the islands, which agrees with our observations of the direction of the current. Especially was this the case north of Guadaloupe and near St. Christopher and Saba islands. Again, in the Anegada passage I saw the same string of gulf-weed stretching in lines to the northward. There was a great deal of gulf-weed north of St. Domingo the 1st of May, passing through the Windward passage and south of Cuba; but I saw none south of Jamaica or over the Pedro and Rosalind banks in the same month, nor did I notice the presence of this weed in the latter locality in January, February, March, and April of 1880.

I was very much puzzled over a current experienced on the passage from Kingston, Jamaica, to St. Thomas, in the latter part of December, 1879. The trades were very strong from the eastward, but we had an easterly current of nearly two knots against wind and sea as far as the Mona passage, and a knot to St. Thomas. The captain of an English telegraph steamer whom I met at St. Thomas, who had been three years in the waters in question, stated that he had always found the current setting to the eastward; and I was given the same current by a number of English men-of-war. No dates were given. It is marked on the chart that the current sets to the eastward during the full and change of the moon. North of Guadaloupe, by observation and dead reckoning, we found the current northerly in the latter part of April; after leaving Saba island the current was N. N. W., about a mile per hour: on our way from St. Christopher to St. Thomas we had a current of one mile per hour setting to the eastward in the same month.

The temperature of the surface water from Barbadoes to the Windward passage was from 79° to 80°; in calm weather, in the day-time, it would rise as high as 81°. This was from March, at Barbadoes, to

May, in the Windward passage. In January, 1880, we found the temperature of the surface water in the old Bahama channel and at the Windward passage only 76°. This gradually increased, as we went to the westward and the season advanced, to 78°, 79°, and 80° near the Caymans, in March, and to 81° and even 82°, in May, between the Misteriosa bank and the Yucatan passage. Over the Pedro and Rosalind banks, and north of the Mosquito coast, it was 79° and 79½°, in February and March.

The bottom obtained in the soundings directly on the ridges was generally coral sand and dead coral; on each side, in the deeper water, it was pteropod ooze. As I shall speak so often of this ooze, I may as well describe it now. After reaching a depth of four or five hundred fathoms, we always brought up a light brown or coffee-and-milk colored paste. This paste is formed of innumerable pteropod shells. The pteropod belongs to the division of mollusca, and is characterized by having broad fleshy wing-like appendages or organs of motion. The shell is transparent and very beautiful. This form of life lives at the surface, and when the animal dies the shell sinks to the bottom, and there decomposes and forms the paste or ooze spoken of. In sifting the ooze collected in the trawl, we found a great many whole pteropod shells.

The Mona passage was thoroughly sounded, and the greatest depth was found to be only 260 fathoms; the islands of St. Domingo and Porto Rico being connected by a plateau of like character with Porto Rico.

It will be seen by the soundings from Grenada northward, that the connecting ridges have the same character of mountain and valley as the lands which they connect. Between Martinique and Guadaloupe, we found a peak in mid channel with only 40 fathoms, deepening on all sides to several hundred.

The bottom in the Mona passage was very hard, and no specimens were obtained. The surface of the connecting ridge seemed swept of everything. The wind was very strong while we were at work here, and the current west of Porto Rico set to the southward near the island, but at the west side of the passage the current set to the northward; this was in May. From the Mona Passage soundings were taken every 20 miles, on the way to the Windward passage, north of St. Domingo. The depth averages over 2,000 fathoms with a bottom temperature of 36½° to 37°. There was a light easterly breeze here, and we found the current to the westward at the rate of 1½ knots per hour.

A very good profile was made of the ridge connecting Cuba with Haiti the first season, and this was verified and many new soundings were added last winter. The deepest water on the ridge was less than 800 fathoms. The temperature at 700 fathoms was 40°; below 700 fathoms, 39½°; and the same temperature was always found at all depths below 700 fathoms in the Western Caribbean by the Blake while under my command, and by Lieutenant-Commander Sigsbee in the same vessel in the Gulf of Mexico. The temperatures outside of the ridge at this passage were: 800 fathoms, 39°; 1,000 fathoms, 38½°; 1,200 fathoms, 38°; 1,500 fathoms, 37½°; 2,000 fathoms, 37°. Inside of the ridge the temperature was constant at 39½° from 750 fathoms to 1,900 fathoms, 10 miles inside the ridge, and to 3,000 fathoms farther on. The first season we were not able to get any specimens on the ridge at the Windward passage with the sounding cylinder, except a few small stones. The moment we crossed the immediate ridge on either side, the bottom was pteropod ooze. Last winter I made two hauls of the dredge in 700 fathoms directly on the ridge. The dredge brought up a quantity of hard coral rock or crust torn from the bottom. It had very much the appearance of old mortar, and was similar to the coral rock found on the northwestern end of Haiti, this part of the island being of coral to the very tops of the mountains. The southwestern end of the island is of volcanic formation, and is covered with luxuriant foliage, but at St. Ncholas Mole it is barren. The land, as seen from the sea, lies in terraces. Barbadoes is of similar formation in terraces to 300 feet above the sea, and all coral.

The second haul of the dredge was near Cape Maysi, still in 700 fathoms. The same bottom was found, also hundreds of shells of the "Scalpellum regium" (a kind of barnacle), which is described by Sir C. Wyville Thomson in his "Voyage of the Challenger." These shells were black and looked very old.

A few very small sponges and sea-urchins were brought up, but everything that could be swept away by a current was wanting. As I remarked before, all the ooze brought up, when sifted in water, was found to contain many whole pteropod shells, but my attention was particularly drawn to the fact that south of the ridge the ooze contained many more whole shells than that obtained to the northward. The current must have swept them off the ridge. While sounding between Miraporos island and Cay Verde, in 1,400 fathoms, the sounding cylinder came up literally packed with these shells. The current in which they were suspended is here retarded by the Bahama banks, and they fall

in this eddy; of course they must be falling everywhere, but here they seemed in excess of any other place. The old Bahama channel was thoroughly sounded by the Blake, the least depth being abreast of Paradon light, 284 fathoms; 500 fathoms abreast Lobos Cay light (this depth was taken over a sounding marked on the chart 900 fathoms, no bottom). A great many soundings were taken between Jamaica and the south-west end of Haiti, the result being the development of a narrow channel connecting the waters of the main Caribbean with the waters north of Jamaica. This channel runs close to Haiti, with a greatest depth of 1,200 fathoms, the bottom temperature 39½°, and a general depth of 1,000 fathoms. The bottom everywhere was ooze. South of Navassa we found a large bed of the pteropod shells. The course of this channel is northerly along the western end of Haiti, where it does not exceed a width of five or six miles, thence westerly south of Navassa island, with a tongue to the northward and another to the westward between Formigas bank and Jamaica. We were here in the latter part of January, spending some ten days. We always found the current setting to the eastward, from one-half to one knot per hour. We met the English squadron at Port Royal, and I examined the logs of various vessels; all had found the same current setting to the eastward as far as the Mona passage. Jamaica was connected by soundings and several temperatures with the Mosquito coast *via* the Pedro and Rosalind bank. The depths between Jamaica and the Pedro bank were: from Jamaica, 322, 320, 293, 236, 381 and 447 fathoms, the temperature of the latter sounding being 44½°. My map was too small to draw the 500 fathoms curve, but the water to a depth of 600 fathoms makes in well to the westward, south of Jamaica. We spent eight days under the lee of N. E. Cay waiting for a lull in the trades to do the next channel; but it did not come, and we returned to Kingston, remaining there two weeks. Two lines only were run between the Pedro and Rosalind banks. The depths across were: 440, 675, 733, 642, 688, 609, 561, 478, 435 and 264 fathoms. The lowest bottom temperature was at 733 fathoms, 40°, the others all above 40°. I think it very probable that there is less water to the eastward of where we ran our lines. There was a little more than 200 fathoms in the narrow passage west of the Rosalind bank.

The bottom in the channels was very fine coral sand, not the smooth bottom found where there was a strong current. The current during February, March, and April did not seem to be setting to the westward through these channels, except in the very narrow one west of the Ros-

alind bank. Several captains of vessels reported a northerly current to the eastward of these banks. To the eastward of Portland Rock, the eastern extreme of the Pedro bank, we found a very strong easterly current in the latter part of February, the trades blowing a gale at the time. A line of soundings was run from Santiago de Cuba to the east end of Jamaica, and a depth of 3,000 fathoms was found 25 miles south of Cuba. Subsequent soundings proved this spot to be the eastern end of an immense deep valley extending from between Cuba and Jamaica to the westward, south of the Cayman Islands as far as the Bay of Honduras.

The Cayman Islands and the Misteriosa bank were found to be a submarine extension (very steep on its southern slope) of the range running along the southeastern side of Cuba. The valley is narrow at its eastern end, but widens between the western end of Jamaica and Cape Cruz, where the soundings were 3,000 fathoms within 15 miles of Cuba, and 2,800 fathoms within 25 miles of Jamaica. This valley is 700 miles long, with an average breadth of 80 miles. It covers an area of over 85,000 square miles, having a depth nowhere less than 2,000 fathoms, except at two or three points which are the summits of submarine mountains, and with the greatest depth of 3,428 fathoms. The low island of Grand Cayman, which stands scarcely 20 feet out of the sea, is really the summit of a mountain 20.568 feet above the bottom of this submarine valley, an altitude exceeding that of any mountain on the North American continent. Between Misteriosa bank and Chinchorro bank the soundings were regular at 2,500 fathoms. North of Misteriosa and Grand Cayman to the Isle of Pines and Cape St. Antonio, the soundings were generally 2,500 fathoms. The bottom everywhere in the western Caribbean is pteropod ooze, with a slight mixture of coral sand, which has been brought up by the wind and water from the islands and keys.

A wide band of westerly current was found south of the Caymans and the Misteriosa bank, turning to the northward at Chinchorro bank, and so following the coast to the Yucatan passage. There was a narrow stream joining this main current from a passage between the Rosalind bank and the Musquito coast, but I did not detect any flow from the other passages. North of the Caymans we found very little, if any, current. There is said to be a current which sets strongly to the eastward south of Cape St. Antonio.

Thus I have given you a summary of the data obtained by the Blake in as brief a form as possible.

The development of the ridges connecting the islands and the deep valley in the western Caribbean sea are certainly very interesting, considered as physical features, and I think that the temperatures obtained at different depths, especially on the ridge at the Windward passage, together with the currents observed, give us facts enough to lay out a possible course for the equatorial current from a point southeast of Barbadoes to the Yucatan passage. There is, certainly, a very large volume of water pouring through the Windward passage, flowing south of Cuba and so on to the Gulf of Mexico; and the temperatures of the water at different depths agree at the same season with those found in the Gulf of Mexico and the course of the Gulf Stream as I have laid it out.

Where does it get this temperature? It is not warmed in the Gulf of Mexico, for the latest theory is that it does *not* flow around this basin. Professor Hilgard, of the Coast Survey, has given a lecture quite recently before the Academy of Science, entitled "The Basin of the Gulf Stream", in which he shows that the current merely enters the passage at Yucatan to be forced by the head of water to the northward and westward out through the Florida straits. The currents in the Gulf are not connected with the Gulf Stream, and are very slow. The temperature is several degrees higher at the same depth at the Windward passage than at the Barbadoes and from Trinidad to Guadaloupe. The comparison of these temperatures is made from observations taken at both places in the months of January and February. The temperature below 800 fathoms in the western Caribbean and Gulf of Mexico could only enter over the rim at the Windward passage and between Haiti and Jamaica; but at the latter point there is no current setting that way; in fact, the pteropod shells showed an eddy.

I suggest that the water of the Gulf Stream is warmed in the main Caribbean, and that there is a possible current flowing around the entire boundary. The equatorial current striking against South America is deflected north, and when it reaches the island of Tobago all that can flow between this island and the main land and south of Grenada does so. This current is said to be felt along the Spanish Main. The greater part of the equatorial current, however, is deflected north between Barbadoes and the Grenadines, finding its way to the westward whenever it meets a passage. Passing through, it would naturally be driven towards the Spanish Main by the trade winds, and thus bank up in the southwestern corner. While working between

the islands south of Guadaloupe, we were always well to windward during the night and therefore felt the northerly set which I wrote of to Mr. Patterson, but north of Guadaloupe, in April, we had comparatively calm weather, and here the current came from the westward, and above Saba island was flowing as if to follow around the Virgin islands. After turning these, it would be helped along towards the Windward passage by the northeast trades.

As stated, the temperature to 400 fathoms suddenly increased, as we passed north of Guadaloupe. Could not this be accounted for by the equatorial current having made the circuit of the main Caribbean and been warmed on its passage over shoals and banks, after traveling nearly 3,000 miles ? The current said to flow along the Spanish Main would be deflected north by the Isthmus and keep on following inside, or to the eastward of the banks connecting Jamaica with the main land, and so south of St. Domingo, to pass out through the Mona passage and the Anegada passage, to flow along north of Porto Rico and St. Domingo to the Windward passage. We found a current in the latter part of April flowing north through the Mona passage and joining the current to the westward. Of course we must have many more facts to substantiate any such theory as I have given. The temperature of the water at different depths must be observed to the eastward of the Anegada passage and over the main Caribbean; and these temperatures must be taken in the same season at the different localities. I will not occupy your attention any longer here, but you can deduce your own theories from the facts given. The contour lines drawn on the map, with the exception of those along the coast of South America, are from the soundings of the Blake. The 100 fathoms curve, is from the United States and English surveys.

Last summer during several weeks the Blake was employed entirely on a dredging cruise, extending from a point off Charleston, S. C., to the Georges banks. Professor Agassiz accompanied the vessel, and named localities for dredging and cared for the life obtained. We had dredged off Charleston in 100 fathoms, then in 200 fathoms. Mr. Agassiz wanted 400 fathoms for the next haul. We steamed to the eastward, but instead of finding deeper water it shoaled. The soundings across the stream were as follows: 142, 198, 225, 217, 236, 229, 258, 334, 382. 364, 337 fathoms.

The next point for dredging was off Cape Hatteras. To reach this point, I kept in the imaginary axis of the stream as marked on the chart, and sounded every five miles, with the following depths: 257, 291, 274, 288, 265, 262, 257, 247, 233, 246, 267, 288, 310, 338, 362,

400. 457, 892, 1,386, the above from lat. 32° 00′ N. to lat. 33° 30′ N.

These soundings were announced in the newspapers as the discovery of a plateau extending from the Carolinas to the Bahamas. This plateau was known at the Coast Survey office. Professor Bache spoke of it as long ago as 1856. He stated: "The discovery has been made that soundings can be carried nearly across the Charleston section of the Gulf Stream, and that after losing them on this section for a short distance, they were reached beyond the axis of the stream, as resulting from the observations of Lieutenants Maffit and Craven, U. S. N., Assistants in the Coast Survey." He says: "The bottom of the sea slopes gradually in this section for some 50 miles, reaching a depth of about 20 fathoms; then more rapidly to above 65 miles and the depth of 100 fathoms, and suddenly falling off to a depth greater than 600 fathoms; at about 100 miles from the shore, where the depth is 300 fathoms, a ridge with a very deep slope on the inshore side, and a little less to seaward, occuring 1,500 feet above the hollow to seaward of it, and distant about 12 miles from it. A second rise of 500 feet, on a base of 12 miles, followed by a depression of 300 feet on a base of 15 miles, and then by a gentle slope upwards. It is altogether probable that all the depths found by observation are greater than the actual ones, but the bottom was brought up in several cases, showing that the lead had reached it. It is most probable that the proportions are not far from correct."

It will be seen how difficult it was to obtain the depth with the old methods. The soundings over this section were reduced one half by the Blake, and at this rate the temperatures taken can hardly be relied upon. We were a little more than two minutes taking these soundings, and always brought up a specimen of the bottom. The temperatures that I find in the diagram of Prof. Bache are not as low as those of the Blake, although we had less water. The season was the same—in July. The temperature of 57° was found at 350 fathoms, and also at 600 fathoms, by Craven and Maffit. The thermometer probably never reached the bottom. We found a temperature of 45° to 46° from 300 to 380 fathoms. The bottom off Charleston was coarse grey sand, black specks, broken shells to 100 fathoms; then fine green sand and black specks, then came coral sand, broken shells, and pteropod shells. As we came more into the stream, the bottom was washed bare, but the cylinder brought up small pieces of coral rock and coral sand. Mr. Agassiz has reported on the life obtained.

As we came north along the Gulf Stream and the water deepened, globerigina ooze began to appear in the bottom specimens. The investi-

gation of the Gulf Stream off Florida and as far as Hatteras, will be renewed by the Blake in the spring. The temperature of the water off the Georges bank in 300 fathoms was 40°. Other soundings and temperatures that we took last summer are interesting, but I must close my remarks, as I wish to speak of the methods of obtaining the results given you this evening. Some of my hearers have probably seen Lt.-Comdr. Sigsbee's very interesting and instructive book, issued by the Coast Survey, on deep sea soundings. I wish all interested in this subject could read it. Lt.-Comdr. Sigsbee was in command of the Blake for four years, and sounded the whole of the Gulf of Mexico, making the necessary examination into its physical conditions. Most of our apparatus was either invented by this officer, or are improvements on known methods.

The Blake is a small steamer of 350 tons, belonging to the Coast Survey. She is manned by eight officers and 38 men, and is fitted expressly for deep sea sounding and dredging. It has been my good fortune to have associated with me on this duty, officers who have rivaled me in their interest in the work. The great work done by the Blake bears testimony to their earnestness, and the records to their care and precision.

The Chairman: I have listened with much interest to the paper which has just been read, and I am sure that all will join me in extending thanks to Comr. Bartlett for giving us the results of his labors in this very interesting form.

Those of us who have had occasion to sail along the south coast of San Domingo have noticed the easterly set which has been mentioned by the lecturer. His explanation of it is naturally suggested by the form and position of the shoals in the western Caribbean, and is probably the true one.

While it is doubtless true that the bulk of the equatorial current sweeps north through the Yucatan Passage, I do not think that Comr. Bartlett means to assert that the whole of it does so. I think it is equally unquestionable that part of the current is deflected across the Campeche Bank, and thence along the coast of Mexico. Of course, the force of this current varies with the wind and season, but I do not think 1½ to 2 knots at all unusual, particularly across the Banks.

I am glad to know that it is the intention of Comr. Bartlett to furnish the Institute with another paper, to embody the results of the next season's work. I think we may anticipate from the coming investigations, discoveries that will be even more valuable and interesting than those which we have had the pleasure of hearing about this evening.


CHART OF THE
GULF OF MEXICO
AND
CARIBBEAN SEA
Contour lines, except in the main Caribbean Sea from Pedro Bank to Grenada, from soundings taken in steamer "Blake" under the direction of C. P. Patterson, Superintendent, by Lt. Comdr. C. D. Sigsbee and Comdr. J. R. Bartlett, U. S. N., Assistants Coast and Geodetic Survey.
under 100 fathoms
1000 fathom curve
2000 " "
3000 " "
GULF OF MEXICO
SIGSBEE DEEP
FLORIDA
YUCATAN PASSAGE
YUCATAN
ISLAND OF CUBA
WINDWARD PASSAGE
HAITI
ST. DOMINGO
MONA PASSAGE
PORTO RICO
ANEGADA
ST. CROIX
ANTIGUA
GUADALOUPE
DOMINICA
MARTINIQUE
ST. LUCIA
ST. VINCENT
BARBADOES
GRENADA
TRINIDAD
GRAND CAYMAN
MISTERIOSA
BARTLETT DEEP
JAMAICA
ROSALIND
PEDRO BANK
CARIBBEAN SEA
HONDURAS
MOSQUITO COAST
PACIFIC OCEAN
95°
90°
85°
80°
75°
70°
65°
60°
30°
25°
20°
15°
10°

PRIZE ESSAY.

1881.

BUREAU OF ORDNANCE, NAVY DEPARTMENT,

WASHINGTON, MARCH 8, 1881.

Lieut. CHARLES BELKNAP, U. S. N.,

Secretary U. S. Naval Institute.

SIR:—

We have carefully perused the four essays sent in competition for the annual prize offered by the U. S. Naval Institute, for 1881, and we consider that the essay bearing the motto, "*Aut Cæsar, aut nullus*" should be classed first in order of merit.

Very respectfully,

WILLIAM N. JEFFERS, Commodore, U. S. N.
JOHN LENTHALL, Chief Constructor, U. S. N.

NAVY YARD, BOSTON, FEBRUARY 7, 1881.

DEAR SIR:—

In compliance with the request of the Executive Committee of the Naval Institute, conveyed in your letter of Nov. 15, 1880, I have examined the essays, four in number, received in competition for the prize of 1881, and have to report my opinion of their merit in order as follows:—

1st. "*In via virtute, via nulla.*"
2nd. "*Fors clavigera.*"
3d. "*Aut Cæsar, aut nullus.*"
4th. "*Pro patria.*"

I beg to add that neither of the essays embraces a complete plan with proper drawings, dimensions and descriptions of "The Type of (I) Armored Vessel, (II) Cruiser Best Suited to the Present Needs of the United States", with reasons assigned why the types should be adopted. In fact, the largest share of each of the essays is taken up with matter foreign to the subject of the prize essay.

Yours truly,

J. W. KING, Chief Engineer, U. S. N.

Lieut. C. Belknap,
Secretary Naval Institute,
Annapolis, Maryland.

THE TYPE OF (I) ARMORED VESSEL, (II) CRUISER, BEST SUITED TO THE PRESENT NEEDS OF THE UNITED STATES.

By Lieut. E. W. Very, U. S. N.

"*Aut Cœsar, aut nullus.*"

In the treatment of the subject proposed for competition, there are two radically different courses that may be pursued. By the first, which may not inaptly be termed the method of induction, a type of vessel may be selected which shall show the development of some one or more excellencies to an extreme; and, having fully worked out all the details of its constructional points, it becomes an easy matter to cite individual instances involving different combinations of attack and defence that shall prove this type to be the one best suited to the needs of the country. This is the method that is most generally adopted either by those who give but a casual attention to the subject or by those who, having at some time past become especially attracted by certain elements of naval strength, have from force of constant thinking and argument come to treat them as hobbies to be applied everywhere and under all circumstances. It is from following this method that we find devotees of an exclusive type of ram, torpedo vessel, gun boat, or heavy armored defence vessel.

The second method, or the one of deduction, is the one which the writer proposes to follow. It is proposed in what follows, 1st, to determine what the necessities are calling for the use of a navy, 2nd, to determine the importance of, and amount of variation in, the services required of vessels in the fulfilment of the demands of these necessities, 3rd, to determine what types amongst those represented in different navies may be safely excluded from consideration on account of the lack of probability of an urgent necessity arising for their use, 4th, to select from the remaining types the ones best calculated to deal with the necessities which will either certainly or most probably arise, 5th, to describe in detail the modifications which these most probable necessities demand. It is considered that this is the true

method of determining the types of vessels best suited to the needs of the country.

The types of naval vessels best suited to the needs of any maritime nation are those which are best adapted to fulfil the services that such vessels will be called upon to perform; the character of the services, depending upon the circumstances most liable to occur giving rise to necessities for a navy.

Before, therefore, any just rules can be laid down for guidance in the establishment of architectural types, a thorough examination must first be made into the different conditions of international intercourse giving rise to necessities for a navy. The circumstances governing the occurrence of these necessities being known, it is then necessary to examine into the probabilities of their occurrence in the case of the particular nation under consideration as determined by the geographical and political situations of the country; for upon these probabilities depend the importance of, and the amount of variation in, the character of the services required; the former quality determining the power of the standing navy both as a whole and as regards individual vessels, and the latter determining the limitations in type.

The circumstances which may occur giving rise to necessities for a navy are common to all maritime nations from the nature of commercial intercourse and international responsibilities, and it is by no means rare to find the possibility of the occurrence of one or more of them, in some especial contingency, quoted as a sufficient reason for the development of a particular type of vessels. If this be a true method of determination then obviously all the possible necessities must be provided for. An examination of all the necessities will show however that the existence of some calls for a force of superior strength to that of another nation, and since the necessities are common to all, this method leads to a striving after the impossible.

The truth of this argument is clearly demonstrated in considering the development of the French iron-clad fleet under the second empire with the result obtained. This fleet was developed with the sole view of attaining a superiority of sea-going strength over Great Britain, and consequently over every other nation; as is made manifest by the discussions of the French naval budgets of 1855—70. The probability of the occurrence of a war with Prussia was, for several years, much greater than that of a war with Great Britain, and when it came, the powerful French iron-clad fleet proved utterly unfit for the main necessity that arose for its use, namely, the blockade of Prussian sea-

ports. The great draught of the iron-clads and the expense of keeping them in their stations made them useless for the purpose. It is therefore the certainity or the great probability of the occurrence of one or more of these necessities that must truly determine the proper type of development.

Nations are guided in their intercourse with each other in accordance with the conditions imposed by a state of war or peace. According to the existence of these conditions any single nation is with respect to another, a belligerent, an ally, a neutral, or in a state of perfect amity; each condition giving rise to duties and necessities peculiar to itself.

The necessities which may arise in any maritime country for a navy, growing out of a condition of a belligerent may be classified as follows: 1st, the defence of seaports and the mouths of rivers and bays; 2nd, the prevention of a blockade of these ports and rivers, or the breaking up of a blockade already established; 3rd, the protection of national commerce; 4th, the breaking up of the enemy's commerce; 5th, the crippling of the enemy's naval force; 6th, the blockading of an enemy's ports; 7th, the transportation and convoy of land forces and the assistance of armies landed in an enemy's country.

From an examination of these necessities, with the view of ascertaining the probability of their occurrence in the case of a war in which the United States is concerned, it is found that the services of naval vessels in protecting national commerce will inevitably be required, for the following reasons. An attack on the commerce of a nation is one of the most effective measures to be employed in war, since it inflicts a great injury by the use of a small force. The magnitude of the injury does not depend simply on the amount of commerce actually captured or sunk, but upon the total value of that branch of industry and the power of the government to give it efficient protection. Since the United States possesses a commerce of constantly increasing importance, and since its nature deprives it of the property of self-protection, a navy becomes necessary. That this need will arise in the case of a war with a nation possessed of a navy is certain, but to be inevitable it must apply to all cases. The condition of United States commerce at the close of the civil war demonstrates what can be done by a belligerent without a navy. Its ruin was complete although at the outset the enemy possessed no sea-going navy, and throughout the war his seaports were closely blockaded; indeed the injury was mainly due

to the devastations of a vessel that, during her entire life time of four years, never entered a southern port. From this example it may be safely inferred that under any circumstances of war United States commerce will be attacked and therefore will need a defence.

The necessity for crippling the enemy's naval force is co-existent with the necessity for protecting commerce and this reason alone is sufficient to establish the certainty of its occurrence. The necessity for breaking up an enemy's commerce may, in the case of the United States, be considered a certainty, for the following reasons. In a war with Great Britain or France possessing powerful fleets that may act offensively on our coasts from bases not far distant, attacks on this very important commerce become a necessity, not only to deprive them of a source of income and channel of supply, but, what is of more vital importance, to divert fleets from offensive to defensive operations. In case of war with nearly every other nation the distance of the countries from each other precluding land operations renders attacks on commerce the main method of carrying on a war.

There are two classes of necessities that may arise calling for a naval defence of seaports and bays: 1st, those resulting from regular attacks by a strong force of the enemy, having for an object the destruction of the land and water defences, the capture of a seaport, or the establishment of a landing point for troops; 2nd, those arising from the dashes of single cruisers into weakly defended ports for the object of destroying commerce and supply depots or for obtaining fresh supplies of provisions and fuel. The great distance of United States coast ports from an enemy's base of action renders the probability of the occurrence of the first class of but slight magnitude except in so far as a war with England, France or Spain is concerned. But this same reason, together with the immense extent and vulnerability of the coast, renders the liability very great with regard to the occurrence of the second. Rapid cruisers, engaged in assaults on United States commerce, and hampered by the laws of neutrality from getting supplies in foreign ports near the United States, will undoubtedly run great risks in making dashes into weakly defended ports in order to renew supplies. That such actions will take place in a war with any nation cannot be established as certain, but the fact that they are of common occurrence in maritime warfare renders the general probability of sufficient magnitude to call for serious attention.

The probability of a blockade of United States ports by an enemy cannot be considered great except in the case of war with Great Brit-

ain or France, for the reason that a blockade, being the most difficult and expensive of all maritime operations in any case, is, in the case of the United States, lacking in the most essential feature necessary to success; the vicinity of a base of operations. The difficulty of maintaining a blockade of even nominal value in the absence of a base of operations in the vicinity is fully evidenced by the results of the blockade of the mouth of the Elbe by the French in the late German war. In spite of the strong iron-clad fleet kept cruising in those waters, the regular trips of German mail-steamers were never stopped, and although German iron-clads did not get to sea, the rigidity of the blockade cannot be claimed to have been the cause of detention. A blockade of one or two United States ports would not inflict an injury commensurate with the expense of maintenance. To be effective, all the great ports from Portland to Baltimore must be thoroughly sealed, necessitating an immense fleet operating over a great expanse, and even then leaving free the whole southern coast.

The probability of a blockade of an enemy's ports cannot be considered of even ordinary magnitude except in the cases of the colonial ports in the vicinity of the United States and in these cases the probability is entirely dependent on the circumstances. For example; a blockade of Cuba would be probable, as it could be accomplished without difficulty and would inflict a great injury on Spain. A blockade of Bermuda is improbable, since its maintenance would be doubtful and the expense would be greater than the injury inflicted. The only operation that could be carried on against that island would be the one of actual capture.

The necessity for the transportation and convoy of land forces is, with regard to the United States of the least of all probabilities, for the reason that except in so far as Mexico is concerned, and perhaps the Central American nations, and the colonial possessions in the vicinity of the country, land operations would not be undertaken. With Mexico the probability would be slight owing to the more advantageous method of land advance.

The duties and necessities arising from the condition of an ally are comprehended in those of a belligerent and being of a similar nature require no especial examination. In the condition of a neutral a nation is bound to maintain a position of amity towards all nations that are at war and with whom the government is in friendly relations. This duty requires that no aid shall be given to one of the belligerents beyond the requirements of common humanity that shall be prejudicial

to the warlike status of the other. The necessities which may arise in any maritime neutral nation, calling for the services of a navy may be classified as follows: 1st, to prevent its citizens from supplying a belligerent with articles that are recognised as contraband of war; 2nd, to prevent the giving of aid and shelter to a belligerent beyond the requirements of common humanity; 3d, to prevent the carrying on of warlike operations by a belligerent within the neutral territory; 4th, to protect national life and property in belligerent territory from danger during warlike operations; 5th, to prevent an unjust interference by a belligerent with the rights of neutral commerce.

Examining these circumstances, as has been done in the case of war, it is found that a very strong probability exists of the occurrence of the first named necessity. The United States furnishes the greatest market in the world for small-arms and small-arm ammunition, and since war itself is the main cause for a demand for such articles it is not to be expected that manufacturers will of their own volition respect the obligations of neutrality in the prosecution of their business. There is therefore almost an absolute certainty that in case of any war, United States citizens will attempt to violate neutrality by furnishing one if not both of the belligerents with munitions of war. The same circumstances will exist and in but a slightly less degree with regard to attempts to furnish fast cruisers or commence destroying vessels. It may be claimed that all such attempts will be frustrated by the use of proper preventive measures of a land-police character, not requiring the use of naval vessels. The escape of a single cargo of arms or a single armed vessel from national territory constitutes however a sufficient breach of neutrality, provided all possible attempts have not been made by the government to prevent it. If it can be established that the timely use of a naval vessel would have prevented the escape, the United States could not plead the non possession of a navy as an excuse for the breach. The government is able to support a navy and, being able, it is its bounden duty to have one if circumstances exist where the services of naval vessels may protect its neutral position.

With regard to the second circumstance, the probability exists but it is of slight magnitude. A vessel of a belligerent may seek a United States seaport for the purpose of renewing her fuel or supplies, and it is not to be expected that citizens will withold these articles when fair and probably high remuneration is offered. In any case the vessel is a power in herself, and an exhibition of corresponding power may be

necessary to enforce a command to either leave or remain in a port when ordered to. The third circumstance although far from being a certainty is of a much greater probability than the second. Belligerents in pursuit of each other's commerce would probably send their cruisers to the vicinity of United States coasts, if such commerce frequents it. In such cases the temptation is irresistible to trespass upon neutral territory in chasing merchant vessels or, when cruisers are at anchor in or sailing through neutral waters, to send expeditions of warlike character to operate either within or without those waters. Such actions must be prevented at all hazards and they can only be prevented by the use of naval vessels.

The fourth circumstance must be considered as inevitable. United States citizens in the pursuit of trade or pleasure are found at all times in all countries; and, wherever warlike operations are carried on by other than barbarous nations, there will certainly be found citizens who through necessity or carelessness are in danger of losing either life or property. The Government owes a protection to its citizens and such protection can only be surely given by placing them upon inviolable United States territory. In by far the majority of cases such protection is only to be found on vessels of war. The fifth circumstance is of remote probability, but its occurrence brings about a condition of imperfect neutrality. The dangers to which occurrences giving rise to an interference are exposed renders a navy, as a preventive power by an exhibition of force present at the seat of war, a constant necessity.

In a condition of perfect amity, a nation is bound to make every exertion to preserve the amicable relations existing and to strive to ensure a peaceful adjustment of all differences that may arise with other Powers. The circumstances that give rise to necessities for a navy in time of peace may be classified as follows: 1st, To prevent citizens of the country or foreigners within the national territory from violating the laws of amity by actively sustaining foreign insurrection or rebellions, or from making arbitrary acts of reprisal for injuries done by citizens of a friendly nation; 2nd, To protect the lives and property of United States citizens in danger from mobs or insurrections within the territory of a friendly nation; 3rd, To call the attention of another nation to the immediate necessity of arranging differences, or to warn foreign citizens against the performance of arbitrary acts injurious to United States commercial rights; 4th, To aid in obtaining a correct knowledge of the waters and coasts of the world by means of

exploring and surveying expeditions, and to aid and extend the interests of commerce.

The first circumstance is one of constant liability in the United States, owing to the cosmopolitan character of its inhabitants and, in a measure, to the popular idea of American born people that foreign insurrections are invariably revolutions of people bound down by monarchical oppression from which there is no other way of escape, thus calling for the active sympathy of a great and self-ruling people. Let disturbances arise in any country and active supporters of it will be found in the United States, who, either through a lack of responsibility arising from their unnaturalized condition, or through a misunderstanding of the principles of liberty, upon which the government is founded, will not hesitate to perform overt acts in violation of international amity. The disturbed condition of Ireland presents such a situation to-day. Cuba, Hayti, Mexico, Central America, France, Italy, Hungary and so on in the list, back to the birth of the country, furnish repeated instances of the necessity for the use of naval vessels by the United States to prevent violations of the laws of amity. The natural desire of mankind to resent in person injuries inflicted gives rise to a necessity for naval vessels to prevent the commission of acts of reprisal. It is but a few months since this danger arose from the arbitrary acts of citizens of Newfoundland in attacking American fishermen. Vessels of war were required on the banks to prevent reprisals by our citizens, which would have complicated the questions raised by the original difficulty. Contingencies of a similar nature may be safely predicted, but their exact form cannot be surmised. Vessels of war must be in readiness to meet them on the instant that they occur.

The second circumstance is one of constant occurrence; the lawlessness and violence of mobs requiring immediate aid for peaceable citizens. Although the danger may be foreseen and provided for in time, where insurrections occur in civilized countries, the case is reversed in semi-civilized nations. The third circumstance, although approaching a condition of imperfect amity, is often of the greatest use in preserving peace. Examples of the necessity and the efficacy of an exhibition of force have repeatedly occurred in the relations of the United States with Spain. It occurred at the time of the French occupation of Mexico; again in the settlement of a question with the Bey of Tripoli, but a few years ago; in Mexico, Venezuela, and the South Sea Islands. All governments are subject at times to the

baneful influences of unreflecting passion, demagogic conceit, or arbitrary ambition, and when questions arise between nations, however reasonable the demands of one may be, an exhibition of a determination to uphold its rights, even at the hazard of war, is liable to become necessary when the other is subject to one of these influences. It is but a few months since Spanish vessels of war stopped and searched commercial vessels of the United States, in direct violation of the laws of amity, and, although the acts were disavowed by Spain, vessels of war were made necessary to visit Cuban waters as a visible warning to the colonial officers not to repeat an offence that they had judged would be condoned by their superiors.

The fourth circumstance is of constant existence. Dependence cannot be placed either upon private enterprise or foreign research to obtain the information necessary for the maintenance and development of commerce. Both naval personnel and matériel, in whatever form they exist, are best fitted for carrying on the necessary work.

Having thus established the existence of necessities for naval vessels, under all conditions of the country, the next step is to determine the importance of and amount of variation in the services required. The past history of the United States, and the well established policy of non-interference with the affairs of foreign nations, give firm ground for the assertion that the normal condition of the nation is one of either perfect amity or neutrality; therefore the composition of the standing navy must be such as will primarily satisfy the conditions imposed by these circumstances. Under all circumstances requiring actions of restraint towards people within territorial limits, (internal insurrections excepted, which require separate examination), the necessity for naval vessels is subordinate to other means of restraint and no formidable strength is required, since no naval strength exists to oppose to it. In these cases, therefore, unarmored vessels of moderate dimensions suited to the requirements of cruisers are sufficient to fulfil the purpose. Since however these duties require the pursuit and arrest of escaping vessels, these cruisers must be given power to sustain a high rate of speed for a great distance. In order to prevent citizens from committing acts of reprisal, the same conditions hold; fighting power is not necessary but great speed is all-important. With regard to attempts made by foreign naval vessels to use United States territory as a base of operations or to violate neutrality by trespass, it may be safely asserted that a simple warning or protest would almost inevitably suffice. But naval vessels are neces-

sary to give this warning, and to enable them to properly do the service they must be cruisers capable of policing the ocean territory of the country and keeping at sea for protracted periods. Insurrections and rebellions in foreign countries or wars between nations are of constant occurrence, and when they break out naval vessels are immediately required to afford an asylum for United States citizens and property in danger. This service cannot be performed by merchant vessels for two excellent reasons: 1st, they do not form a part of the inviolable territory of the United States nor are they authorised to act directly for the government; 2nd, they lack the power to resist lawless attacks upon them and are themselves in need of protection. The duties of naval vessels in these cases are peaceful in their nature and require no more of an exhibition of strength than is necessary to guard against lawless acts. Hence for such services unarmored cruisers of moderate dimensions are sufficient. In the cases of outbreaks in semi-civilized countries, although the object of the required service is peaceful, a positive exhibition of strength is necessary in order to overawe the mobs, since peaceful negotiations are of themselves no guarantee of safety. None of these nations or provinces, however, except Turkey and Egypt, possess a naval force of even moderate strength and their seaports are poorly defended. In addition to this, an uprising, although it may only affect the citizens of one foreign nation, invariably brings at once the vessels of war of several others to the threatened point, all united in supporting the common cause of civilization. Unarmored vessels therefore are capable of furnishing sufficient strength to meet the necessities, although much of the result depends upon size and actual power of the vessels.

Although wars may be foreseen and the exigencies be provided for at comparative leisure, insurrections and individual acts of violence can never be long foretold. Hence the necessity for squadrons of cruisers in time of peace, ready to act at any threatened point at short notice, and, from what has preceded, these squadrons may be composed of unarmored vessels, mainly of moderate dimensions, and, on stations comprising the territories of semi-civilized nations, having a few of the heavier classes.

There remain the cases of a necessity to prevent an unjust interference by a belligerent in the rights of neutral commerce, and the circumstance of calling the attention of a foreign power to the immediate necessity of arranging differences. Both of these circumstances call for the services of vessels of war only after the failure of a protest

through the diplomatic department of the government; and the bringing forward of naval vessels is in both cases an act clearly bordering on one of war. Much therefore depends upon the course adopted by the government concerned. The policy of the United States is, as has been already stated, one of extreme reserve as to foreign affairs, and in its execution repeated examples may be given showing that the fact that circumstances are such that there is simply a danger of an unjust interference in the rights of neutral commerce is not considered sufficient to justify the use of a naval force; indeed it is questionable if even a strong protest would be considered politic against anything short of an overt act. To make this point clear (and it is necessary so to do in order to determine the requisite naval strength) the actions of the British and United States governments are cited with regard to affairs on the coast of Spain in 1873. In that year the Spanish government was engaged in suppressing insurrections in its southern provinces. The insurgents gained possession of several men-of-war, and, hoisting the red flag, an unrecognized ensign, cruised along the coast levying tribute on the seaports and Spanish merchant vessels. The Vittoria and Almansa were captured by a British iron-clad squadron, under the plea that, although they had not interfered directly with British commerce, they had endangered its rights. The act of the British Admiral was upheld by his government. United States war vessels were on that coast and the national commerce was subjected to the same risks from the lawless acts of the "Intransigentes," but orders were issued by the government, on no account to interfere except an overt act were committed. An act of a very similar nature was performed by a British admiral on the coast of Peru some years afterward. Such being the policy of Great Britain, and nearly all maritime nations possessing armored vessels, the necessity exists for that country to have armored cruisers in peace as well as in war; and, with equal truth, the opposite policy of the United States does away with the necessity for such vessels in time of peace.

The necessity has repeatedly arisen for the United States to make a display of naval strength to call the attention of Spain to the urgency of matters of dispute between the two countries. Such displays, however, only occur after overt hostile acts by Spaniards, and a stringent restraint is always placed upon the proceedings of the fleet. That peaceful negotiations have but glossed over without remedying the evils is a patent fact, and it is equally patent that the possession of a naval force of ten times the strength would not add anything to the satisfac-

tion of the case. Herein lies the weakness of the argument of those who advocate powerful fleets for the United States. That a prompt recognition of the rights of the United States commerce in Cuban waters demanded a few years ago a display of force, of both armored and unarmored vessels, no one acquainted with the circumstances is disposed to deny; but, if it be the policy of the government to permit the safety of commerce to be jeopardized, and to sacrifice commercial interests by seeking unsatisfactory remedies, then the necessities for a navy in such cases, either do not exist, or, if existing, are of secondary importance. The United States, whatever be its policy, must have a navy to aid in sustaining the neutrality and belligerent rights of other nations, as the non-maintenance of one brings a risk of war. She either needs or does not need a navy for the protection of her own interests, according to whether her policy is to support or neglect those interests. Experience shows, however, that at times the government considers it necessary to make a display of force, and as this brings about a strained condition liable to lead to war, a certain element of armored strength is required for the emergency.

In accordance with these analyses then, it has been established that for the standing navy in time of peace or neutrality an active force of unarmored vessels is necessary, proportioned in number to the amount of interests at home and abroad requiring protection. Cruising stations for squadrons are necessary in those parts of the world affected by United States commercial intercourse. Vessels of a medium class are mainly required and these vessels must possess a maximum of speed and capacity for fuel; they must also be provided with full sail-powers, not only as a matter of cruising economy but to enable them to keep the sea for long continued periods. On certain stations these medium vessels must be supplemented by cruisers of the heavier classes. Finally, the navy must possess a certain passive force of the stronger or armored element.

No demonstration is necessary to prove that a naval force must be stronger in time of war than during peace. These peace forces must then, when taken together, serve as a nucleus of the war strength, their power and type being such as will at the same time best fulfil the peace demands and serve the defensive war purposes until a proper war strength can be developed. Since the range in general types of unarmored vessels is quite limited the discussion of the modifications demanded by a state of war may be postponed for the present; but with armored vessels, the great range in types and the normal passive

condition which renders the war modifications paramount, make an especial discussion of these war necessities imperative.

It may be stated as an axiom that for coast-defence and the prevention or breaking up of blockades, armored vessels of what are universally recognized as coast-defence types are the ones most necessary. For the protection of commerce and attacks on an enemy's commerce the armored vessel is not needed. The crippling of the enemy's naval force, may or may not necessitate the use of armored vessels according to the especial object sought to be accomplished. If the enemy's iron-clads appear upon the United States coast, then coast-defence iron-clads are required to meet them. If the enemy's iron-clads cruise at large on the ocean, it is contended that the better policy would be to let them alone. To send iron-clads in search of them would be an undertaking expensive, hazardous, and unsatisfactory. Commercial vessels are in no more danger from them than from unarmored ships and must accept great risks at any rate. If the enemy chooses to waste strength in sending armored vessels on indefinite cruises to cover an immense ocean territory, a false ambition to meet him in hand to hand encounter should certainly not lead the government to follow the example and put great strength where it can do little good. If the enemy's iron-clads attempt to break blockades established, then armored vessels are necessary to frustrate the attempt. In examining the circumstances of these blockades, it is found that Mexico and Central America possess no iron-clads, therefore armored vessels are not urgently required there. Brazil, Argentine Confederation, and Chili possess them, therefore, owing to the great distance of the ports from home, cruising iron clads would be necessary to success. The vicinity of Florida and South Carolina to Cuba and the weakness of the Spanish fleet, combined with the great distance of its home ports, make coast-defence iron-clads thoroughly competent to establish a blockade of its ports. It is confidently asserted that Jamaica and the British West Indies are safe from blockades by the United States, on account of the paramount necessity for the use of the full armored strength in the defence of the coast in case of war with Great Britain. Canada is equally free from blockade dangers for the same reason. Bermuda might be captured, it could not be successfully blockaded. With regard to European ports, an attempted blockade by the United States would be both impolitic and improbable, on account of the lack of a base and the necessity for crossing the ocean only to meet fleets in good condition fresh from

port. With Japan or China, strict blockades would be more expensive and less satisfactory than a system of worrying dashes by unarmored vessels.

Thus, of all the necessities of attack and defense, the blockade of South American ports alone calls imperatively for the use of the cruising iron-clad. A blockade of these ports appears itself imperative, since the prosperity of these countries depends in a very great degree upon a free communication with European Nations. For a passive force then these types are entirely unnecessary, and for an active one the probable necessity is either so slight or so vaguely defined that these types should be left for the war pressure itself to define. In thus condemning the sea-going or cruising types of armored vessels as far as the United States is concerned, more convincing argument still is considered necessary to satisfy the ideas of those who are attracted by the courses adopted in great foreign navies. In the first place, full weight must be given to the exigencies arising in European states from endeavors to preserve the balance of power. These render a condition of peace one of an extremely precarious nature, thus calling for a greater interdependence in type development. The natural desire of Italy, for example, is without doubt to limit the strength of her navy to coast defence types; but her peculiar position in the Mediterranean requires that to maintain her situation as one of the great powers, these coast defence vessels should be of a strength to give her a commanding position in Mediterranean affairs. Her Duilios and Lepantos must oppose an effective barrier against the too vigorous assertions of power of the Inflexibles and Duperrés. The United States fears nothing from the latter vessels except in actual war. Italy must fear their domination in the diplomatic actions of peace.

Policies in different nations are extremely changeable, and their instability not only demands greater peace strength but the slight necessities of one day become serious the next, therefore greater range in type developments is necessary. Ten years ago the imperial policy of France called for foreign cruisers; in two years' time the Republic demanded coast-defence; to-day its demands are general and in a year no one can prophesy what they will be. Ten years ago Russia had no navy in the Black Sea; to-day she is developing her power there and peaceful relations with the rest of Europe are kept at a constant strain. Prussia has become the German Empire with greatly extended coast to defend and enhanced responsibilities as one of the balancing powers of Europe. The policy of great Britain, that nation

that prides itself on its stability, is as changeable as that of any in Europe. Radicals and Conservatives are equally patriotic, and yet in foreign affairs the paths followed by each as it comes into power could scarcely diverge farther, and in nothing is the foreign policy of Great Britain more faithfully reflected than in the successive type developments of its fleet.

Strong navies in close proximity to each other cause again this great interdependence. To none of these circumstances is the United States subject. She is as a great power isolated from foreign political complications. Her policy as far as other nations is concerned is unchangeable and the policies of other nations do not effect her. The circumstances giving rise to necessities for a navy being of a constant nature, the range in types may be reduced to a minimum; and since these necessities are mainly of a defensive character, then the type of armored vessels should also be one suited to coast defence.

Thus far the analysis of the needs of the United States has led to a limitation in the range of armored types from which a choice may be made by excluding those vessels that are generally known as cruising iron-clads. In pursuance of this line of argument the next step is to ascertain what general types of coast defense vessels should or may be excluded, and to determine this point the conditions which a state of defence will force upon the country must first be established. The general problem may be thus stated; Given, a certain amount of armored strength as a mass, how shall it be distributed in order to best defend the coast from threatened or actual attack?

The United States coast, taken as a whole, is in what may be considered a fairly excellent condition of navigability; by this is meant that there are no great stretches so protected by shoals or dangerous passages as to render them difficult of access to an enemy's force. This whole coast must be defended, since scattered along its entire length are sea-ports of great commercial importance. An examination of the general conformation will make at once apparent a peculiarity which should exercise a great influence in the limitation of the type of armored coast-defence vessels. The coast is divided naturally into a series of districts or basins within whose limits inter-communication is readily obtained, but which are so separated from each other as to render it difficult to send vessels rapidly from a point in one to any threatened point in another. These basins may be arbitrarily named as follows: 1st, the Gulf of Maine, limited on one side by the New Brunswick boundary and on the other by the outlying islands and

banks off Cape Cod. 2nd, the North Atlantic, comprising the great bight between Narragansett Bay and Cape Hatteras. 3d, the South Eastern or Carolina, including the crescent between Hatteras and Key West. 4th, the Gulf, from the Florida Keys to the Rio Grande. 5th, the California, from San Diego to Cape Medocino. 6th, the North-Western, from Mendocino to Vancouver. The Alaskan coast is omitted from consideration owing to its present lack of commercial importance.

In the case of a threatened attack from the eastward, it is plain that no estimate could be made as to the point aimed at by a force mustered at Halifax, Bermuda or the West Indies. Although it may be known that an attack in force is contemplated, the point at which it is to be made would only be ascertained through the appearance of the force on the coast. If such an attack were contemplated, it would either be in force, that is, made by an armored squadron, or in a series of running dashes at different important points by single vessels. The first method is only to be feared from Great Britain, France or Spain, as other nations lack the base to work from, and even in these cases a fleet attack is a matter of such magnitude that it could hardly be expected to take place during the first periods of a war. The second may be feared from any nation having armored cruisers, and may be reasonably expected in the first periods of war. The probability being so much the greater in this case must be the first one provided for. The first aim in the development of the defence then should be to prevent such attacks, and, if they cannot be wholly prevented, to break their force.

Owing to this distinctive division of the coast into basins, if a single armored cruiser should suddenly appear off Boston, vessels stationed in New York bay would be debarred from coming to the rescue in time by the necessity of rounding Cape Cod and threading the channels of the Banks. Vessels on the Atlantic coast are powerless to offer rapid relief from attacks in the Gulf. Charleston and Port Royal cannot well be defended from Hampton Roads and vice versa; whilst the defence of the Pacific is entirely separated from that of the Atlantic. Since the coast is so broken and so extensive as to give an advantage to attacking vessels by retarding those sent to the relief, it is certain that the total defensive power cannot be massed in a single heavy vessel. There must be a division into at least six independent parts, the strength of each part being so regulated and distributed as to offer an effective menace against individual assaults within its basin, without immediate reference to that of another.

The magnitude of a thoroughly effective defence may be estimated, as being equal to the sum of the strengths of one armored vessel stationed at each threatened point, the power of such vessels singly being equal to that of the cruiser likely to make the attack. As the points are numerous, the number of vessels and the total power would be very great. Such a total would however represent a war footing, and since the normal condition of the United States is one of peace or neutrality, the constant maintenance of so great a strength is necessary. The peace strength should be just so much as would make it a great risk for single armored vessels to visit the coast during the first periods of war, holding them back until opportunity is given to establish auxiliary harbor-defence and to bring forward the war strength. In order to arrive at this minimum, the risks to which each basin is exposed will be considered separately.

The north-western basin is in the least danger from naval attacks, it being highly improbable that any armored vessel except one from Great Britain, would go so far from its own base of supplies to make an attack that would under no circumstances have other than a local effect. The main risk is then reduced to the chance of a war with Great Britain, in which case Vancouver offers a great vantage ground for attacks all along the Pacific coast. In accordance with our assumed standard of strength, the points in danger in this basin are:—Port Townsend, the key to the de Fuca straits and the sound; Olympia, the head-quarters of the Puget Sound defence, and the Columbia river. Of these three points, the dangerous bar of the Columbia combined with the merely local effect of an attack there, reduces the liability of attack to almost nothing. No attack can be made on Puget Sound without first overcoming the defending force in the straits; therefore the total strength assigned to the defence of this basin is truly represented by the power assigned to Port Townsend.

The British armored force on the Pacific coast has never exceeded one armored vessel which could only be reinforced within a reasonable time by one other iron-clad detached from the China seas. It is evident that the holding of Esquimalt would be of the first importance to Great Britain, since without it operations by an armored squadron or even by single iron-clads would be next to impossible. A force in the straits therefore that should menace the safety of Esquimalt would be a protection to both the North Western and the California basins since it would necessitate the immediate presence of the British force at that point, and the risk of attacks on California being thus reduced, a

certain amount of dependence may be placed upon a reinforcement from that basin. The peace strength necessary then, need only be sufficient to attack Esquimalt with impunity in the absence of an armored enemy, and since the whole fighting ground is limited to a narrow inland water this force may be represented by the strength of a single harbor-defence vessel of moderate power. The presence of this much strength in those waters will *insure* the immediate presence of the whole British armored force at that point, and the exact position of the enemy being known, reinforcement may be given from the California district intelligently.

How shall the strength be distributed? To force the enemy's armored vessels to come north, this strength must be so arranged as to threaten seriously the Esquimalt shore defences, with power to damage if not destroy the dockyard. To hold a large force by a small one it must be so much lighter in draught than the British cruising iron-clad as to enable it to take up a secure inshore position for defence pending a reinforcement that shall permit offensive operations against the enemy's armored vessel. Its general measurements should, however, be sufficiently great to permit of a transfer of the force to the California basin in case the war be with any other nation than Great Britain.

The first requisite of the force excludes from consideration, the Chinese Alpha class of gunboats for harbor-defence, the Ram pure and simple, and the torpedo vessels. Neither of these types can offer a serious menace to shore defences. Plainly then, this strength must be concentrated in a gun-bearing, armored, vessel. Power of artillery must take precedence of number of guns, and her armor must be of the greatest resisting power consistent with the character of the vessel. The character and position of the shore defences demand a calibre of rifled guns not less than nine inches, and these guns must be wholly protected, thus excluding barbette fire. These limitations point directly to the pure monitor type of vessel as being the most suitable. The draught of water must be less than eighteen feet (allowing twenty feet for the minimum draught of English armored cruisers) and experience shows that it should be greater than eleven feet to give her qualities that would enable her to make safely the passage from Puget sound to San Francisco. One more feature requires consideration as tending to limit the power required. Although there is no harbor-defence vessel permanently stationed at Esquimalt it may safely be prophesied that in accordance with British policy, one will be sent there

in the near future, and since its object would be solely to protect the harbor in case of war with the United States the main effective strength of the navy will not be weakened to provide for this single contingency, and this vessel will probably not be of a greater if as great a strength as the "Cerberus" type. A United States vessel then of an equal strength will relieve the whole Pacific coast from danger of attack by armored vessels in the first periods of a war with Great Britain. Before entering upon a discussion of the necessary details of the type, the requirements of other basins will be determined.

The California basin is exposed to attacks from Great Britain, Chili and Japan; the points immediately endangered from single ship attacks being San Francisco and San Diego, the latter point being destined from its position as a great commercial terminus to offer in the near future great temptations to assault.

Two other points are endangered from later operations, although measurably safe during the opening war periods. Monterey bay and the Santa Barbara islands in the hands of the enemy would form excellent bases for naval operations within the basin. Their defence may, however, be left to the later development owing to the necessity for the enemy to mass a considerable force to take and hold the position, or, in other words, it would enter into the measure of the necessary war-strength. The danger of attacks from Chili or Japan on San Francisco may be met thoroughly by the transfer of the force delegated to Puget Sound to that point, since the north western basin is not endangered. Time and opportunity would under all circumstances be sufficiently ample for the purpose. In the case of war with either of these nations therefore the question of defence is reduced to that of San Diego. With regard to Great Britain, it has already been demonstrated that pending the development of a war strength, their armored force may be kept clear of this district by the importance of the interests to be defended by them farther north. To keep them north, however, the armored force of this district must be depended upon.

The magnitude of this relieving force must be sufficient not only to hold a British harbor-defence vessel and an iron-clad cruiser north, but also if possible to confine the freedom of action of the reinforcement from China, forcing a concentration of the enemy's strength instead of allowing it to spread along the whole Pacific coast. Since the iron-clad detailed to draw the enemy north is of only a sufficient strength to neutralize the British harbor-defence vessel, the relieving force must be of a greater total strength. The nature of the service

required demands an armored coast-defence force. Shall it be concentrated in a single vessel or be divided? A single heavy iron-clad would in actual combat possibly represent a sufficient total strength, but in such a combat the probability would be great of having two vessels matched against three, giving the enemy the advantage not only of artillery power but of tactical manœuvring and ramming facilities. Furthermore, the exact demands of the attack and the defence cannot be foreseen. By having a force so concentrated, a superfluity of strength may be sent to one point at the expense of the defence of another. If the force be divided between two vessels, one may be sent north at the first demand, leaving the other to combat an attempt at a diversion. At the outbreak of war suppose one of these vessels to be stationed or to proceed directly to San Diego and the other to remain at San Francisco. With the help of the shore defences these points are safe from attacks by the armored cruiser which must proceed north. As this cruiser leaves the California basin, San Diego becomes relieved from danger, as a vessel coming from China is in no condition to make an attack so far south. She may attempt San Francisco, in which case a harbor-defence vessel is there to meet her. The enemy then has a choice between two courses, either to remain in front of San Francisco blockading this lighter armored vessel or to go to the defence of Esquimalt and thus permit the whole force to concentrate at the north. For the defence of the California basin then two armored vessels of the monitor type are sufficient, and in order that the interests of economy may be considered, it is estimated that one of these vessels may be of the same measurements as the one detailed for the north western basin whilst the other may come within the limits of a light harbor-defence vessel, the limitations being given in the discussion of details.

The Gulf district is in reality open to attacks from the armored cruisers of all European nations, but its naturally protected position combined with the meagreness of results to be obtained by individual attacks reduces the probability of them almost to a nullity so far as armored cruisers are concerned, in all cases except those of wars with England, France or Spain, whose West Indian possessions enable them to strike with equal facility the Gulf or the Atlantic basins. The points that are liable to menace are; Galveston, the mouth of the Mississippi, Mobile, Pensacola and the Florida Keys. Of these, Galveston offers no inducement for the expenditure of armored strength at such a great distance from a base; Mobile is protected by its shal-

low channels and interior position; the mouth of the Mississippi presents but one narrow channel available for sudden attack and this channel may be quickly placed in a condition of secure defence from individual attacks by means of earth-works and torpedoes. Pensacola, as a dock-yard station, offers a temptation for assault sufficient to demand a separate defence. The Florida Keys, being in fact the key to the basin, demand the most attention, as their seizure by an enemy would give him a control of the whole southern coast.

In case of a war with Spain, the vicinity of Cuba to the coast, and the importance of this island to the kingdom, render an attack in force upon it the best method of protecting the whole Atlantic from assault. For a blockade of Cuba, the Florida Keys are of the highest importance as a base of operations, and the whole force of the basin may in this case be treated as one concentrated at this point. It has already been demonstrated that the iron-clad force detailed for this blockade may safely be limited to coast-defence types, and, in view of the limited peace strength permissible, the number of vessels required for a blockade and the condition of the Spanish armored force, these coast defence vessels are most effective if the whole force be divided amongst light armored vessels, a certain amount of dependence being placed upon a reinforcement from the more northern basins, and this dependence is allowable since the main efforts of Spain must be directed to saving Cuba, leaving no spare force for creating a diversion.

If the war be with France it would seem that since the possession of St. Pierre and Miquelon at the north would enable iron-clads to menace the northern basins and thus deprive the south of reinforcement; and the vicinity of the West Indian colonies gives a fair base for action against the southern coast, the main objective point of the French would be the seizure of the Florida Keys which would give them entire control of the Gulf basin and a foothold for attack on the Carolina coast. In this case then, the whole action in this basin is concentrated to the defence of the Keys, and no relief can be planned by an attack on the French possessions, since such an attack would require the use of the greater part if not all of the peace strength devoted to the Atlantic, drawing it too far from the points requiring defence. The same conditions hold, and with greater force, in case of war with Great Britain, with a great risk to Pensacola in addition.

These being the conditions, it is considered that one light iron-clad monitor should be detailed, for the defence of Pensacola in case of war with Great Britain, for a reinforcement of the force at Key West

in case of war with France, or for a menace against Havanah in case of war with Spain; two light monitors for the defence of Tortugas and two more for Key West, giving thus a total for the patrol of the islands that would deter single vessels from attempting a seizure, and a number sufficient to make a good distribution about the Cuban coast pending operations on a greater scale.

The Carolina basin presents no point for obtaining an advantageous foothold by an enemy and four points only under a liability to attack, Wilmington, Port Royal, Charleston and Savannah. Of these, Wilmington and Savannah are self-defending against attacks by individual vessels. A detail of one light monitor for each of the other two points is considered sufficient to deter attacks on them, whilst they may both be used against Cuba with safety. In fact the vicinity of Port Royal to Charleston and the strong shore defence that may be established at that point would permit of sending one of these vessels to the Keys in a war with either France or England, giving them thus five and perhaps six vessels with which to keep the command of the Florida channel and gulf. It may be asked: Why are monitors arbitrarily named as the type of vessels? The answer to this question is that although reasons may be given for even a preference for the ram or the torpedo vessels in a strictly defensive warfare, the probability of war with Spain is greater than that of any other nation. In such a war a blockade of Cuba and seizure of the island is undoubtedly the first step to be taken, and such a step requires the use of armored gun-bearing vessels, and due weight must be given to these limitations in arranging for the defence of the Keys. A type that shall fulfil reasonably all the requirements is preferable to one that may be better for one object but which is totally unfit to meet the strongest probability.

The North Atlantic basin, from its great commercial importance and general accessibility, offers the greatest temptation to attack. Its great distance from any of the foreign colonies forbids offensive measures as a means of protection, as has been cited with regard to Vancouver and Cuba. The force employed must therefore be one of a strictly defensive character, although here, the fact that one half of the dock-yards of the country are within this basin and the central position of the district making it the grand supply and relief depot for the other basins, should exercise a great control in type limitations. The points endangered are; Nantucket whose seizure would give an enemy a most complete base of operations against the whole coast;

Narragansett bay and the eastern entrance of Long Island Sound; New York bay, Delaware bay, and Chesapeake bay. Of these, the naval defences of Delaware and Chesapeake bays are in a position to offer mutual reinforcement, for the following reasons; an attack on Lewes or the Delaware breakwater would only be made with the object of holding it as a base, as nothing is to be gained by a dash at it. An attempt to hold it would be met by a concentration of force sent from the other parts of the basin. Beyond Lewes, no point offers temptation for attack short of Wilmington, and since the presence of the enemy would be known upon his reaching the capes, any operation high up the bay would lead him into a "*cul de sac*," sufficient time being allowed for the despatch of a force from the Chesapeake. Richmond and Washington, on account of their riverine position, may be rapidly placed in security by means of earthworks and torpedoes, whilst Baltimore is similarly situated to Wilmington. Norfolk alone presents a point on which attack may be made with a chance of getting away safely again and even here torpedo defence is applicable. For a strict defence of these positions it may be asserted with much reason that torpedo boats at Wilmington and Norfolk would suffice. This style of defence however would not suffice to keep a single cruiser from patrolling the mouth of the bay and stopping communication with the dock-yards. The ocean highway must be kept at least passably free in the interests of supply and relief of other basins. The armored ram pure and simple might make the risk of keeping an armored cruiser just outside too great to warrant its attempt; but the greatest present probability of war is with Spain, and this event would call for armored gun bearing vessels. In any event it is considered impolitic to sacrifice artillery power entirely to the ram. Since the service of the Delaware bay force is confined to driving cruisers from the vicinity of those waters, it is considered that two light monitors may successfully perform the work, a certain dependence being placed on the defence of the Chesapeake in case points high up the bay are threatened. The same amount of force would suffice in Hampton Roads were it not that the chances of an attack on Norfolk are very great and in any event a reserve must be held for the Delaware. If this reserve consists of one monitor of medium class, the combined force of this and two light monitors would give the advantage to the defence in any individual attack, whilst in a war with Spain this heavier monitor and two light ones could be spared for West Indian service.

The position of Nantucket makes it indisputably the key to both the Atlantic and Gulf of Maine basins. The great commercial importance of New York renders that point especially susceptible to attack, but such an attack, it is contended, to be of any real service to the enemy, must be in force, since it is to be expected that the defending force will be strong in proportion to the importance of the metropolis. In case of a war with either Great Britain or France, no point offers such temptation as Nantucket. A dash by a single armored cruiser supported by a few corvettes and gun boats may result in the capture of the island, and once in the hands of the enemy, it would not only be a difficult matter to recapture it, but the position would establish a complete control over New York and Boston. The importance of the defence delegated to the navy is strikingly exemplified in this case. Vessels of war of the enemy cannot hold points on the mainland as the facilities for a shore defence are almost unlimited. At Nantucket however success by the enemy is secured by the vigilance of a naval force in patrolling the captured waters. It is considered then that in case of a war with either of the above mentioned nations a constant naval defence must be retained at Nantucket and the position of the island demands for the main naval strength at least one armored gun-bearing vessel. If this vessel be a monitor of a medium power, its presence will warn off the enemy's single cruisers from this point. If the cruiser attacks Narragansett bay, the force from Nantucket and Long Island Sound may be quickly concentrated there. If he attacks the Sound the Nantucket force may come to the relief. New York bay, from its distance and position, must have an independent defence. Owing to the position of Narragansett bay between Nantucket and the Sound and the presence of the torpedo station making it natural for an enemy to expect a strong torpedo defence, it is considered sufficient to leave this point to this auxiliary force. The confinement of the eastern entrance of the Sound and the vicinity of Nantucket makes it possible to reduce the defence of this point to two light monitors, thus giving a force strong enough to check an attack pending the arrival of reinforcement, whilst Narragansett or Nantucket may receive reinforcements if they be attacked without leaving the Sound entirely open in case of a feint on the other points. Let it be remembered that a feint on points west of Nantucket although possibly leading to a withdrawal of the force from that point would not only catch the feinting vessel between two fires but would lead to a rapid and certain joining of the whole defending force for a recapture if Nantucket were lost. For this reason

the Nantucket defence is concentrated in a single vessel whilst that of the Sound is divided.

The position of New York bay, removed from the possibility of a quick reinforcement from the other parts of the basin, and the importance of the point to be defended, demands both a strong defence and a concentration of power. In order to ward off individual attacks effectively it is considered that the least strength that can be detailed for this point would be represented by two medium class monitors, and this disposition, whilst securing the port itself, would permit operations tending to keep the whole bight clear of cruisers by the aid of the threatening position of the defending vessels at Nantucket, the Sound, and Delaware bay.

In the case of a war with any nation except Great Britain it is considered that but three points in the Gulf of Maine basin offer temptations to attack; these are Portland, Portsmouth and Boston. No point in this basin would be available for establishing a base of operations against the coast since Cape Cod effectually breaks the connection. In case of war with Great Britain, the Maine coast may be threatened by operations in conjunction with measures for invasion from New Brunswick. In this case, however, mere attacks on the verge of the coast would be unsatisfactory, and the risk from torpedoes and earthworks is considered sufficient to keep iron-clad cruisers from the rivers. The armored defence, then, may be considered as confined to these three points. The immediate harbor defence of Boston may be safely entrusted to auxiliary defences, but since communication with the city may be blocked by a single cruiser patrolling the waters between Marblehead and Cohasset, it is considered that two light monitors are necessary to insure the clearance of this point. Portsmouth is a point of greater importance to the defence than Portland, and owing to the position of its dockyard rendering the latter assailable and subject to damage by an attacking vessel without entering the Piscataqua river, it is considered that one medium class monitor is required at this point, not alone to secure it, but to afford a quick concentration for the relief of Boston and Portland and to add to the individual weight required as protection for this basin which is so isolated from more southern points. Such a vessel offers also a strong protection to Nantucket, in connection with the vessel stationed there, and those at the Sound and New York. Finally, since Portland offers no thorough defence through torpedoes and shore works, and in view of the self-dependence thrown on this basin for its total defence, a force of one light monitor is considered necessary for this point.

The discussion with regard to types of armored vessels best suited to the needs of the United States has taken the ground that owing to the geographical and political position of the country, the types should be limited to coast defence vessels; and, owing to the limitation of total requisite strength brought about by the normal peaceful condition of the country, this power, in the interests of economy, should be divided principally amongst light harbor-defence vessels. These vessels should be able to support heavy guns and armor on account of the services required in beating off armored cruisers, and certain sea-going qualities are demanded; 1st, in the Pacific, on account of the necessity of making passages between San Diego, the Santa Barbara Islands, San Francisco and Puget Sound; 2nd, in the Gulf, for the patrol of the Florida Keys and the blockade of Cuba; 3rd, in the Atlantic basin, for the reciprocal support between Delaware and Chesapeake bays and for the defence and reinforcement of Nantucket; 4th, in the Gulf of Maine, on account of the isolation of the basin and the necessity for a quick concentration at certain points. Great weight of armor and artillery, combined with a fair modicum of sea-going power, is best combined in the monitor type of vessels and it is with the details of this type that the final discussion will deal.

In the generally accepted classification of coast-defence vessels, those known as light armored vessels are such as do not exceed a displacement of two thousand tons. There are in the United States Navy now many monitors of the original type coming within the prescribed limit of displacement tonnage, and, starting with these as a basis, it will be shown in what manner they may be modified to fulfil the present requirements. It is not the part of an essay to enter into the minutiæ of calculations, nor can fully detailed drawings and descriptions of a typical vessel find a place in such a monograph. In discussing the modifications, however, whilst no exact standard can be given by which to measure the correctness of the deductions, every point advanced may be substantiated sufficiently to prove its tenability, and such will be the course adopted. It is proposed to so modify these monitors as to give them an increase of artillery power, a greater command of artillery (height above water-line), an increase of freeboard to give them better sea-going qualities, an increase of armor protection, speed, manœuvring qualities, and ramming power; and all whilst keeping within the displacement limits.

The armament of the 1900 ton monitors consists of two fifteen-inch smooth-bores with their attachments. In view of the work

which such vessels will have to perform, these guns should if possible be replaced by long ten inch steel breech-loading rifles; that is, by guns capable of piercing a fourteen inch wrought iron plate at five hundred yards. The long rifle must be a breech-loader, in order to keep the size of turret within reasonable bounds and to give proper loading facilities. The results of the proof firings of foreign guns, and the development of steel manufacture, point to the necessity of using this metal as the construction material. Finally, whilst a power of penetration of fourteen inches at five hundred yards is sufficient to overcome the defensive strength of the majority of the cruising iron-clads afloat, it is considered to be considerably within the limit of a ten-inch gun of twenty-five calibres length; for the reason that, whilst the English short ten inch penetrates 12.7 inches at that distance, Krupp claims with his thirty calibre nine and a fourth inch gun to attain a penetration of sixteen and three-fourths inches.

The following comparison of weights shows that the substitution can be made, without calling in aid weight that is distributed elsewhere.

XV. Inch Smooth Bore.		Long 10 Inch Steel Rifle.	
2 Guns at 45,000 lbs.,	40 tons.	2 Guns at 41,000 lbs.,	36½ tons.
2 Carriages and slides at 18,000 lbs,	16 "	2 Carriages and slides at 21,000 lbs.,	19 "
100 Rounds, half shot and half shell at 507 lbs.,	22½ "	100 Rounds, chilled projectiles at 470 lbs.,	21 "
Total	78½ "	Total	76½ "

In this estimate the minimum weight is given to the smooth bores and the maximum to the rifles. Furthermore, the weight given to the rifle includes the appliances necessary for a center port pivoting carriage, and, since the length of the gun forbids the use of the present port-stoppers, the weight assigned to them may safely be allowed for the increase in the turret weight due to a reduction in the size of the port, it being proposed to abolish port-stoppers or shutters, this being the course adopted throughout Europe. The danger of disabling a gun by the jamming of a shutter is greater than that of the entry of a projectile into the port. The shot that would enter a port would smash or jam a shutter, whilst the same result may happen by a hit in the vicinity only of the port.

The present style of mounting a turret on a spindle is faulty in the extreme, and it is proposed to replace it by the turn-table system now in universal use, the increase in weight due to this change being esti-

mated as safely within two tons. Although the change in battery gives by estimate a saving of two tons, it will be in our estimate reserved as a margin for artillery, therefore by the change of turret mounting a weight of two tons is called for.

The 1900 ton monitor is designed for a mean height of deck above the water-line of eighteen inches. It is proposed to reduce this height to nothing by bringing the crown of the deck to the water-line, the side armor stopping also at this point. From the water-line it is proposed to carry up an iron unarmored freeboard fore and aft to a height of six feet, crowned by a wooden flush deck.

The reasons for the proposed reduction of height of armored deck are as follows. With the present height of eighteen inches, opportunity is given for a projectile striking at or just above the water line to open a serious leak underneath the armored deck into the submerged sections of the ship. In this case, the height of the between deck space decreases the dependence that may be placed in the reserve buoyancy of the vessel, no matter how thoroughly this part of the ship may be subdivided by water tight compartments; it brings the small but important additional strengthening due to the waterways and thickness of the deck too far above the water line to be of good service and it increases the size of the dangerous space laid bare in rolling and pitching. An increase of the freeboard permits this deck to be lowered by giving an increase of reserve buoyancy. Projectiles penetrating at or above the water line open water-courses into compartments where the minimum of evil effect is produced, since, being above water they are easily cleared, whilst the safety of the under water sections from flooding is preserved and their area is reduced. The slight increased protection offered by the deck against penetration of the side is carried down to the most vital point, and a material reduction in weight of side armor is effected. In the construction of all European iron-clads, these considerations lead to placing the armored deck even much lower down, it being generally found at or near the lower edge of the armor. In these monitors, however, the necessarily light draught giving a reduction of available height for boilers and engines, the probability that combats in which these vestake part will be in comparatively still water, and the small surplus of buoyancy allowed, necessitates fixing the height of the deck at the water-line, the water-ways being somewhat below in accordance with the round-up allowed to the deck.

In thus lowering the height of the armored side a material saving of

weight is realized, which may be estimated at one seventh of the total weight of side armor (this estimate allows an original total height of armor of seven feet, which is at least six inches more than is actually the case). The weight thus saved it is proposed to utilize in the construction of the unarmored superstructure or additional freeboard. As before stated this superstructure gives a clear freeboard of six feet all around. The iron for its construction may be $\frac{3}{8}$ of an inch in thickness, with a six inch wooden backing or skin, such a combination furnishing the strength necessary to meet the strains to which it would be subjected in a seaway, whilst the backing reduces the shattering effect of piercing projectiles. Assuming the thickness of the strip of armor that has been removed to be five inches, (in reality the average thickness is considerably greater), it will be found that only three-tenths of the weight is required for the iron plating; five-tenths is certainly an ample allowance for the angle iron frames, stringers, and light upper deck beams, leaving one-fifth of the weight to go towards making up the backing and the upper deck. This amount would without doubt suffice for the backing alone, but to make it certain the weight of the upper deck will be drawn from another source. The backing and sheathing of the armored deck it is proposed to leave in its present form, with the exception that, in place of the iron, steel two inch plates be introduced, whereby a saving of weight is gained which may be allowed to go into the backing of the superstructure, thus securing it from an under estimate.

As a matter of course, the turret must be raised to give a clear fire over this superstructure; that is, its height is increased six feet, and provision must be made for that much increase of armored protection about it. In mounting the turret it is proposed to adopt the French system rather than the English. That is, instead of having the turret mechanism protected by what may be termed an outside casemate, with a glacis at the joint, to make the turn-table smaller, resting it on the periphery of a second turret whose exterior diameter is slightly less than the interior of the turret proper, the latter resting on the rollers through the medium of a shelf-piece or ring around its interior lower part. The lower edge of the turret is carried down one foot lower than at present, covering the joint and protecting the rollers. The second turret, or, as it may be called, the casemate, since it is fixed and protects the space between the armored deck and the turret proper, should be of the same composition as the upper one. The weight of the turret proper as at present arranged is about a hundred and

ninety-six tons. Increasing its depth by one foot, to give the required protection to the joint gives an additional weight of twenty-two tons, whilst the weight of the casemate calculated in accordance with the measurements of the turrets is sixty tons; add to this two tons estimated for the change in the revolving mechanism, twelve tons for five water-tight bulkheads intended for the division of the superstructure, and twenty tons for the upper deck, and a total weight of a hundred and sixteen tons is reached, which must be drawn from some other source. It is intended to leave the weights and position of the pilot-house, smoke stack, air duct and accessories, above the armored deck, as at present.

In the discussion thus far, the weights considered have been disposed as would be found on a monitor of the Lehigh class, that is on a wooden hull. This hull absorbs, as near as can be estimated, somewhat over sixty-two per cent. of her entire displacement tonnage. The best European authorities give as the general weight of iron hull of monitor types of vessels from thirty-two to thirty-four per cent., falling in the case of the Javari, which is of the type under consideration but whose extremely flat bottom lightens the necessary weight considerably, to twenty-nine per cent. In the transformation of the Miantonomah, the hull is over-weighted, reaching fifty per cent. These lighter monitors however should certainly not pass forty per cent., and by making this the limit of weight, a saving is made in a two thousand ton vessel of four hundred and forty-four tons. This is a perfectly legitimate deduction, since the weights that have been treated of have been borne by United States monitors of eighteen hundred and twenty-one hundred tons, whose hulls by transformation from wood to iron, without alteration of the measurements, may be lightened the above amount of twenty-two per cent. Taking from this saving the accumulated one hundred and sixteen tons, a surplus of three hundred and twenty-four tons remains free for distribution.

Of this amount of spare weight, it is proposed to devote a hundred and forty tons to the engines, boilers and coal supply to give the vessel maximum speed of eleven and a half knots, with fuel for ten days steaming at ten knots. Sixty tons should go to the armor, which, taken in conjunction with a proposed alteration in the side armor, will permit the application of an upper strake over the middle third of the frames of seven inch compound steel and iron plates, diminishing forward and aft to five inch plates, with four inch steel plates at the extreme end sections. The lower strake of armor should be altered to

five inch compound plates with four inch steel forward and abaft the middle third. Finally, the turret armor may be made up of two five-inch plates with a six inch wood backing and a half inch skin plating. In this division, the weight of engines and boilers is increased by six per cent., the coal supply one per cent. and the armor as much as twenty per cent., leaving still a disposable weight of a hundred and twenty-four tons, which great surplus is left to cover all deficiences.

Doubtless this seeming assumption of rough estimates gives but little confidence in their truth. In an essay, however, a more extended particularization is scarcely permissible, and, to give a greater evidence that these estimates are within bounds, attention is drawn to the following points: 1st, an allowance of a hundred and twenty-four tons is made for differences of opinion as to the estimates of the weights cited; 2nd, the distribution of weights gives a heavier hull, lighter engines, boilers, and coal supply, and lighter armor than would be obtained by using the proportions of the displacement found in the average of European vessels of this type; 3rd, the type of vessel described has almost its exact counterpart in the Dutch monitors of the Guinea class, which have proved perfectly satisfactory after a test of from four to ten years.

One more modification requires attention. The elevation of the turret demands an alteration in the lines of the vessel with a view of retaining stability and steadiness in a sea way. The reduction in the height of the side armor compensates in a degree for this elevation of weight. For the general form of the hull, that adopted in the new Miantonomoh is proposed, gaining thus a well-proportioned and powerful ram. Whilst the length between perpendiculars and breadth of beam remain about the same as in the Lehigh class, the draught is increased one foot.

It is understood then, that the type of harbor-defence or light armored vessel proposed, is in general the same as the present United States single turreted monitor, the main alterations consisting in the elevation of the turret six feet, giving greater command of artillery fire in smooth water, and facilities for going safely into action in a sea-way, the addition of an unarmored superstructure six feet in height, adding to the sea-going qualities by giving a better freeboard, furnishing better quarters for officers and crew, and by bringing them up above the armored deck, increasing the spare space below so that room is given for the necessary increase of engine and coal space; lowering the armored deck to a better position, and giving the vessel a ram and a more pronounced dead-rise.

The apparently weak point about this typical vessel is the unarmored superstructure, and since in the opinion of the writer of the essay it may be applied without endangering the safety of the vessel in action, a word in its defence is necessary. It is assumed that no seaman will deny that such a superstructure increases the sea-going qualities of the vessel, provided that the lines of the ship are so trimmed as to at least retain her original stability and steadiness, and certainly this is far within the limits of possibility. The danger from this superstructure is then entirely confined to the possibility of flooding it in action and destroying the reserve buoyancy. Now it is claimed that the maximum of defensive power has been given to the monitor from the water line down, which would not be materially increased by adding to it the weight allowed for the superstructure, which in any event would go more to strengthening the middle than the end sections. A projectile penetrating the side below the armored deck gives rise to the greatest possible danger, therefore it needs no demonstration to show that this deck should be placed as low down as possible, due regard being had to other requirements. In this respect then the addition of a superstructure permitting the bringing of this deck to the water-line increases the defensive strength of the vessel. It will be argued that if this superstructure be punched full of holes, the reserve buoyancy will be destroyed. Now it is argued that holes in it which are three feet above the water-line will not seriously endanger the buoyancy, except a combat be in a seaway that would seriously hamper if not entirely prevent an action. It is held therefore that the danger is limited to a strake three feet in height above the water-line. Now this superstructure weight has allowed for five transverse bulkheads, and it is claimed that allowing a shot coming in forward to pierce all five bulkheads, making such a gap that one of them could be filled in so short a time as two minutes, the resistance to the flow of the water offered by even remnants of the others, would permit those compartments to be kept easily free of water by steam pumps of ordinary power. To endanger the safety, therefore, all the compartments must be pierced, each by more than one shot. It is claimed that this will not happen in engagements between iron-clads, for the reason that the enemy will seek not to destroy these compartments but to strike the water-line, turret, steering gear and other vital parts. The truth of this assertion seems to be eminently supported by examining the results of actions between vessels happening within the past twenty years. It would seem as if the last action of the Huascar offered a fair example of the destruc-

tion that might be expected. This vessel was placed between two fires and sustained an action at close range for over an hour. She was disabled and captured, and yet her reserve buoyancy was not seriously threatened, although she presented a target not unlike the one proposed. In the melee of Lissa, the artillery fire did not endanger the buoyancy of any vessel in either fleet, although certainly some of the vessels were hit and pierced enough to satisfy the demands of any one. The only case in which the danger does occur is in a prolonged attack at short range on coast defences, and herein lies the basis of the whole argument. In the well-known discussion with regard to the Inflexible's lack of reserve stability, it was not her danger in fighting iron-clads that was feared but her weakness in sustaining prolonged attacks on shore defences. It was pointed out in a former portion of this essay that these light monitors are not intended for such work except as auxiliaries, their province being essentially ship-fighting; heavier iron-clads must be provided for dealing with the coast fortifications. It is contended therefore that the superstructure is under all circumstances a benefit and in no case a danger.

Since this arrangement of superstructure is faulty in the case of attacks on shore-defences, an expansion of the type in the heavier monitors will not prove satisfactory, and an alteration becomes necessary. In the opinion of the writer of this essay, all the qualities demanded of these heavier monitors are found most advantageously distributed in vessels copied without change from the Orion and Belleisle type of British iron-clad vessels, or, to use a name more generally known, in the Dreadnought class of vessels reduced. It is considered, although no calculations have been made to ensure the estimate, that by substituting compound steel and iron armor for the iron of the Belleisle, carrying in the casemate, so that it will barely enclose the turrets, transferring the pilot-house and mounting it on a spindle over the forward turret, abolishing the large glacis, made necessary by the system of muzzle loading, and substituting steel breech-loading twelve inch guns for the Woolwich type, such a reduction in weight will be made that the displacement may be reduced to forty-two hundred tons and the maximum draft to within eighteen feet.

These then constitute the types of iron-clad vessels best suited to the present needs of the United States. It is plain that none of the old iron-clads can be economically rebuilt to meet the requirements demanded, but, whilst these vessels still retain a semblance of strength, a wise system of construction will enable the substitution to be made

quietly, certainly, and without any appreciable increase in the yearly amount appropriated for constructional purposes. The following table shows the proposed peace strength and its distribution.

Name of Basin.	Needs of the Basin for Armored Vessels.	Armored Strength Detailed.			
		Number of Vessels.	Total Displacement Tonnage.	Per cent. of Total Force.	Artillery Power.
North Western and California.	To secure California coast ports from attack in case of war with Chili or Japan by having at each threatened point a vessel able to contend with the enemy. In case of war with Great Britain, to seriously menace the safety of Vancouver and to present a force sufficiently strong to cope with British armored strength in the Pacific.	3	10,400	16½	Eight 12 inch, and two 10 inch B. L. Rifles.
Gulf.	To assume offensive operations speedily against Cuba in case of war with Spain. In a war with Great Britain or France to protect the naval stations of Pensacola and Key West, and prevent the enemy from seizing and holding the Florida Keys.	5	10,000	15¾	Ten 10 inch B. L. Rifles.
Carolina.	To protect Charleston and Port Royal from the raids of armored vessels and to reinforce the vessels detailed for the protection of the Florida Keys, or the blockade of Cuba.	2	4,000	6¼	Four 10 inch B. L. Rifles.
North Atlantic.	To prevent the enemy from seizing and holding Nantucket; to protect the naval establishments of Newport, New London New York, Philadelphia, Norfolk and Washington, to secure the safety of the commercial metropolis of the Country and to prevent armored cruisers from patrolling the most important basin of the whole coast.	10	28,800	45½	Sixteen 12 in., and Twelve 10 in. B.L. Rifles.
Gulf of Maine.	To protect the naval station of Portsmouth, to prevent raids by armored vessels into this partially isolated but important basin, to aid in the defence of Nantucket, and in case of war with Great Britain or France to force the maintenance of a strong naval power at Halifax, or St. Pierre and Miquelon.	4	10,200	16	Four 12 inch, and four 10 inch B. L. Rifles.
	Total Peace Strength.	24	63,400		28 12 in. 32 10 in.

Displacement Tonnage of the existing armored strength, 52,360
" " armored strength on the Pacific coast, 3,590

The circumstances governing the general type limitations of the unarmored fleet have already been discussed, and it only remains to give the details of the modifications required to fit them for the present

needs. The total effective unarmored strength of the United States at the present time, including all steam vessels of a displacement exceeding three hundred tons, except the heavy navy yard tugs, is represented by fifty two steam vessels; and it is considered that, judging from the present squadron demands, the methods of cruising and relieving, and the yearly appropriations that may be depended upon, if these vessels were all in a condition to be made available within six months from any given time, they would be sufficient to fairly fulfil the necessities of foreign and home service. Since, however, the prolonged or arduous service under certain circumstances reduces the effectiveness of ships to such a degree that they are made unavailable for a year or more, it is considered that the full *cadre* of the navy list should not fall short of sixty vessels off the stocks, in order to realize a force of fifty vessels available within six months.

It has been demonstrated that this force should be mainly composed of vessels of a medium class, reinforced by a contingent of heavier vessels on certain squadrons where their services may be suddenly required. Since the main services of all these vessels are confined to the necessities of peace or neutrality, the element of economy must have great weight in the distribution of the force. Furthermore, the limited number of men allowed for the total active personnel exerts a great influence on the regulation of the displacement tonnage.

Of all the different stations occupied as cruising grounds by United States squadrons, the Mediterranean, Asiatic, and Home require in their complement at least one vessel of the heaviest class represented in the Navy, the first two squadrons on account of reasons heretofore given, the last because of the great probability that in case of a war or a disturbance threatening one, the Atlantic coast would become the theatre of the most immediate and active operations. In order that this representation shall be continuous, the number must be doubled in order to allow a relief vessel. The isolation of the Pacific coast and the strength of foreign squadrons kept in those waters demand an allowance of certainly one vessel capable of carrying the heaviest battery to be used by unarmored ships, and in the total complement one more is allowed to make up for loss of services due to repairs of over a year's duration. In this estimate, then, eight vessels are allowed for the highest tonnage, or about thirteen per cent. of the total number. It seems to be well established that vessels of the Minnesota class are too heavy for economical service, and the results obtained from the prolonged cruise of the Trenton seem to point to this vessel

as representing a satisfactory maximum weight. The course adopted in all foreign navies, as well as the teachings of the experience of the last twenty years in our own, distinctly point to the wisdom of having the main body of the Navy consist of vessels ranging in displacement tonnage between one thousand and twenty four hundred, that is, from ships of the Swatara class to those of the Alaska, and it is considered that whilst sixty per cent. of the force should consist of these vessels, the interests of economy and effectiveness are best served by having double the number of the lighter vessels, or, to give more exact limitations, to have twelve ships of from two thousand to twenty four hundred tons displacement, and twenty four of from eleven hundred to eighteen hundred tons. By this arrangement, there are left of our total force sixteen vessels for a tonnage of from six hundred to one thousand.

Taking the Trenton as a basis in the discussion of the modifications required, it is considered; 1st, that a greater effectiveness would be secured by reducing the calibres of her broadside battery and increasing the number of guns. Her battery, as it stands at present, has a calibre at least a half an inch greater than the average found in European vessels of a similar tonnage. In the development of smoothbore ordnance, it was certainly a wise policy of the United States government to keep a high range of calibre even at a sacrifice of number of guns, but whilst the resisting power of the sides of unarmored vessels remains the same or in fact has become less, the great increase in power gained by the introduction of the rifled gun, has led to a possibility of overreaching the effective limit. This, it is considered, has been done in the case of the Trenton. Comparing her with the British Euryalus, it seems unquestionable that the sixteen seven inch guns of the latter vessel are superior in effectiveness to the eleven eight inch guns of the former. In a broadside action the Euryalus brings nine guns into action againt six of the Trenton's. It is suggested that for the gun-deck battery of this vessel ten long seven-inch steel breech-loading rifles be substituted for the eight-inch, thereby saving in weight at least three tons.

In order to secure a powerful bow-fire, arrangements are made on the Trenton for transporting the forward pair of main deck guns to forward ports, the bow-frames being given a flare out at the gun-deck, and the hawse-holes being carried down below the gun-deck beams. Any arrangement by which broadside guns must be shifted in order to command increased firing angle is faulty, in that it requires limitations

in the position of hatches, chains, galley, and other important adjuncts of a gun-deck outfit. Furthermore, as long as head-booms with their rigging are carried, no reasonably good bow-fire can be secured from the gun-deck. It is contended that all bow-fire belongs properly to the spar-deck equipment where only it can be made effective. It is suggested, therefore, that the hawse-pipes be restored to their normal position, and, whilst one port in addition to the bridle-port is left free for use in certain unforeseen contingencies of action, that the ten guns be put in broadside strictly with a view to their being fought in their proper ports.

In the arrangement of the spar-deck battery especial attention should be given to securing good fore and aft fire which is necessarily neglected on the gun-deck. In place of the present pair of eight-inch bow guns, which unquestionably over weight the extreme bow and give but a doubtful straight ahead fire, a single seven-inch is proposed, which will certainly have as great a command. By suppressing the channel-ways and setting the rigging up at the water-ways as is done in all French first and second rates, two seven-inch guns may be mounted in projecting half turrets just abaft the fore top-mast, backstays, giving a complete forward and beam fire without encumbering the gangways. Two other seven-inch guns should be mounted just forward of the mizzen rigging in the same manner, whilst abaft the mizzen-mast a single seven-inch pivot mounted amidships completes the after fire. With this disposition the Trenton secures the same broadside strength as the Euryalus, with an increased fore-and-aft command. With five more guns than are carried at present the total weight is not increased, nor is efficacy sacrificed. The bow-fire is reduced from a doubtful four gun command to a certain three gun one, whilst the bow itself is relieved from a great weight and the hawse-pipes are brought up to their proper position.

2nd. The ship herself should be built of iron, sheathed with wood and coppered, having a double bottom and wing passages. No explanation of the necessity of this modification is necessary.

3d. The weight saved by these modifications of hull and battery should be devoted to an increase of the horse power of the engines and the coal supply.

4th. A modification is urged as being of great importance, although hitherto it has received but slight attention in the United States. In all foreign men-of-war of the first or second class, it will be found that a bridge is erected forward of the foremast for the officer of the watch,

and on this bridge is placed the service steering wheel. By this arrangement those persons upon whom the whole safety of the ship depends at night are placed in a position where, under all circumstances, they may act intelligently. The officer of the watch has the helmsman and the binnacle compasses directly under his eyes, and is not obliged to depend either upon the vigilance of others for keeping a proper lookout forward, nor upon the watchfulness of a quarter-master in keeping a steady course. The suggestion of this modification, as having a direct bearing upon alteration in type, may appear superfluous, but since it deals with the removal of the steering-wheel from its time honored place at the mizzen-mast it is considered of sufficient account to be noticed, especially as it is liable to meet with opposition from those who are married to the old styles and principles. With the minor modifications influencing ventilation, light, cleanliness, and the general sanitary condition, it is considered the essay is not called upon to deal. The type of vessel, then, represented by the Trenton, with these modifications, is the one proposed for the heaviest rate.

It may be urged and doubtless will be with reason that there are many circumstances of action, especially against shore defences where the seven-inch rifle will be scarcely of sufficient power to accomplish desired ends. To meet these exigencies batteries containing this calibre must be provided, and it would seem that the next smaller rate of vessel offers good opportunity for the disposition. The Alaska is taken as the basis of this type, her counterpart being found in improved condition in the C class of British corvettes. These vessels like the heavier ones should be built of iron, sheathed, with double bottom and wing passages. It is proposed that the under water lines of these vesssels be kept as at present, their great excellence having been fully established. It is proposed that the top-gallant forecastle be lengthened somewhat in order to give galley room and increased berthing space. For the battery, it is proposed to mount a sixty-pdr. rifle on the forecastle as at present, just abaft the forecastle an eight-inch rifle pivot-gun, and a similar one on the quarter deck, eight six-and-a-half inch rifles in broadside, and at the break of the poop a modification is proposed having for its object an opening of the stern fire command with an increase of weight of broadside. The English method of accomplishing this result is by mounting a single seven-inch gun on turn-tables in the cabin, the quarter upper works being cut in to open the fire. There are two objections to this style. First;—it makes necessary the faulty shifting pivot, which in

this case is much more complicated than with the American system of swinging about a long slide. Second, it destroys a great amount of valuable space. It is now the general custom to decorate the quarters of all vessels with large quarter-galleries, which are no doubt greatly conducive to the comfort of the commanding officer. If, in place of these, similar uncovered galleries be built out on the spar-deck level at the break of the poop, room is given for the introduction of two sixty-pdr. rifles that will give a clear stern and beam fire. By this arrangement, whilst one less gun is carried than in the C class of corvettes, the same number of guns is given for a broadside with an increase of weight of metal due to a greater concentration of battery and a greater command of stern fire, whilst the eight-inch calibre necessary for heavy work is provided. All nations consider it of great importance to open a clear stern fire. The method adopted by the British is the one generally followed. In France however the poop-cabin is suppressed and a heavy center pivot rifle gives good all-around fire. In the United States Navy it is the invariable custom to completely block the stern and quarter fire by the poop-cabin. The method suggested above, it is urged, is practicable, and thoroughly accomplishes the object without a waste of space.

The next class of vessels is represented by the Essex, and since the size of this vessel especially adapts her for a commerce destroyer, which service, as was demonstrated, is one of the main war probabilities for the United States, her battery should be arranged with a special view to this service. For this reason it is proposed to develop the strength of bow-fire to the utmost, and to thoroughly accomplish this it is proposed to suppress the present forecastle pivot and heavy forward rifle pivot. In place of these guns, two sixty-pdr. rifles are proposed to be mounted in ports well forward of the fore rigging, the side forward being cut back sufficient to give a clear bow-fire. Abaft these guns, two six-and-a-half-inch rifles in broadside and on the quarter deck, two six-and-a-half-inch and two sixty-pdrs., the latter in galleries for opening the stern fire as heretofore described. This arrangement gives a good all-around fire and a maximum of broadside, whilst all guns are kept on the broadside carriages. These vessels should be of composite build, and it is proposed that a clear gangway shall reign from the steerages forward to the berth-deck. The galleys should both in this and the other spar-deck vessels go under the top-gallant forecastle.

The lowest class of vessels proposed should resemble in general type the next higher, a change being made in the disposition of battery corresponding with the services which their light draught is liable to impose upon them. Since the next higher class has a battery composed entirely of medium calibred guns, these smaller ones should fill the gap in weight of metal as is done by the second class with reference to the first. The battery proposed is, four sixty-pdrs, two forward and two aft, arranged as in the next higher class to open fore and aft fire, two seven-inch pivot rifles, one forward and one aft. These vessels should be composite built.

In this, then, is represented the total proposed unarmored fleet for general service. Although the bows of all should be heavily strengthened and provided with collision bulkheads as a preparation for a resort to ramming, the application of a forged snout is not recommended for any except the first class, the others not being able to carry it, on account of the fine lines forward and the necessity for securing as much buoyancy forward as possible. The assemblage of the force is represented in the following table.

UNARMORED FLEET.

Class.	Number of Vessels.	Limits of Displacement Tonnage.	Aggregate Tonnage.	Battery.
First	8	3800 to 4000	31200	Sixteen 7-Inch Long B. L. Rifles.
Second	12	2200 to 2400	27600	Two 8 " " " Eight 6½ " " " Three 60 pdr. " " "
Third	24	1300 to 1500	33600	Four 6½ " " " Four 60 pdr. " " "
Fourth	16	900 to 1100	16000	Two 7 " " " Four 60 pdr. " " "
Total	60		108400	

Present displacement tonnage of the unarmored fleet, 107,690.
Proposed Increase represented in eight additional vessels, 710 tons.

It may be considered that in view of the great increase in tonnage proposed for the armored fleet which is the passive one, the small supplement of 710 tons for a constantly active fleet is ridiculously small, but there are several considerations that must not be lost sight of: 1st, of the total present tonnage, a very large proportion is swallowed up in the vessels of the Wabash class which is a clear loss to the active force; 2nd, in this actual tonnage several vessels are counted which in reality have no business on the active list; 3d, in case of the sudden outbreak of war the unarmored fleet can be readily reinforced by vessels drawn from the merchant marine and new vessels can be quickly constructed; 4th, the unarmored fleet represents the offensive and the armored fleet the defensive strength of the country. To the latter then must be given the most thorough development. The first need of the country is for a secure defence, and, whilst, the small unarmored fleet is sufficient to prevent complications in time of peace, it is in this very time of peace that the armored defensive strength should be carefully and strongly developed, that it may form the strong backbone of the Navy, able to support the hastily constructed auxiliaries that a war would bring forth.

THE EFFECT OF GREAT COLD UPON MAGNETISM.

An investigation upon the magnetic condition of steel and upon the magnetic permeability of iron is now being made in the Physical Laboratory of Harvard University by Prof. John Trowbridge. The preliminary experiments are interesting, since they show that very low temperatures exercise a far greater influence on the magnetic condition than has been noticed by previous observers.

Wiedmann found that a bar of steel which was magnetized at 6°C or 8°C gave at 4°C and —25°C intensities represented by 5.08 and 4.90. This represents a loss of less than four per cent. In Trowbridge's experiments the bar magnetized at 20°C lost when subjected to a temperature of about 60°C a far greater per cent. In one case a bar magnetized to saturation lost sixty-six per cent. In another experiment the bar lost in forty-seven minutes nearly two thirds of its magnetism. After the same bar had been exposed for twenty four hours to the temperature at which it was magnetized its magnetic condition was fifty per cent. of its original state. The low temperature employed was produced by a mixture of solid carbonic acid and ether.

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C. E. M.

TRIAL OF A SECTIONAL 6.5 CM. MOUNTAIN HOWITZER.

This gun tested at Krupp's works was of the following dimensions:—calibre 65mm.; length 1,800mm.; length of bore 1,660mm.; weight including lock 180 kg; number of grooves, 12; depth of groove 1mm.; width of lands 2.5mm.; width of groove 14.5mm.; twist of groove, once in twenty-five calibres; total length of groove 1,625mm. The gun was divided into three parts, the breech with the lock, the chase, and the trunnion section, the two former being joined together by threads upon the latter. For convenience in transport, the piece is divided into two parts only, the trunnion section remaining attached to the chase; and either part may be transported on a single animal. The threads of the screws are protected from damage by brass caps, which screw on by hand. The carriage consists of side pieces of stamped sheet steel properly braced, with elevating screw, steel axle and wheels on the Thovet plan. The carriage ready for action weighs 181 kg.; it allows of 20° elevation and 8° depression to the piece. The charge used is 750 grms. of coarse grained cannon powder. The shell and shrapnel, 3.38 calibres in length, weigh 4.1 kg. The velocity, measured at 40m. from the muzzle, averaged about 394m. Each day of firing, the gun was taken apart and put together, requiring from fifteen to twenty-five seconds for the first operation, and thirty seconds for the last. In range and accuracy the gun was found very satisfactory; the mean range of eight shots, with an elevation of 6° 18′, being 2501.6m.

Translated from the Mittheilungen uber Gegenstande des Artillerie und Genie-Wesens, Fifth Part, 1880, by Prof. C. E. Munroe.

THE TYPE OF (I) ARMORED VESSEL, (II) CRUISER, BEST SUITED TO THE PRESENT NEEDS OF THE UNITED STATES.

By Lieut. Seaton Schroeder, U. S. N.

"In via virtute via nulla."

Mr. President and Gentlemen :—

The attention of this Institute has been invited to the naval defence of our country. At a time when public sentiment, as reflected in the leading papers, appears to be awakening to a sense of our necessities, a more interesting topic could not well be selected.

Of the two principal classes of vessels required to perform the extremely varied duties that devolve upon a fleet, we will first consider—

THE ARMORED VESSEL.

Some eighteen years ago Mr. Ericsson's uncanny looking production gave a most vigorous, almost a creative, impulse to a wave of revolution in naval warfare. That wave left our shores soon after, to ebb and flow in all the channels of human knowledge and ingenuity that so enlighten parts of the old world. It would ill become us, at this juncture, to close our eyes to the panorama spread before us, and remain insensible to the march of professional thought and the development of mechanical skill.

In Great Britain's magnificent, heterogeneous fleet, all the changes have been rung in the theory as well as practice of naval architecture, until one principle now seems to have been adopted, to which others are subordinated. While that country in her liberality has been carrying on experiments, even to the extent of subjecting one class to an ordeal ruder than is probable in war, many other nations have clung to earlier ideas, or sometimes have accepted the results obtained by their insular friends.

Different foreign policies regulate the cost of construction and maintenance of fleets; but the formation and geographical situation of coasts must have a voice in determining some points in the individual ships composing those fleets. Designers of vessels should first exam-

ine the special requirements for the protection of certain coasts. In all cases this does not seem to have been very carefully done. In the old world we see one country, centrally situated in the placid Mediterranean, whose naval administrators are vesting their means in huge floating targets, carrying guns at a height of thirty-two feet above the water. In the new world, whose shores, far from being washed by a placid sea, are noted as among the most dangerous in certain seasons, the naval defense is entrusted to vessels with thirty inches of freeboard, and guns about six feet from the water. True in the latter case great bays are found everywhere and shelters for unseaworthy craft are numerous, while in the former they are the exception. But, in the one case, the ability to obtain a plunging fire hardly seems to out-weigh the great cost and unwieldiness, while, in the other, the smallness of the target presented seems to be extreme when it results in helplessness in a sea way.

The coasts of the United States have twice the development of those of Italy, and sending a force from point to point in the Atlantic cannot always be done under as favorable circumstances as in the Mediterranean. Our isolation is often quoted as an element of defence, no powerful iron-clad being able to cross the ocean and have coal enough left on board to warrant blockading or attacking the ports or bays where our little monitors and torpedo-boats would harass them. That theory is fallacious, and the supporters of it must forget the convenient coaling and resting places that several nations have at our very threshhold. The only benefit derived from our isolation is that we are the less apt to be drawn into other nations' quarrels.

Whether we are to build vessels or not lies with our legislators. But, if the means are supplied, what we require is a vessel that can proceed in any weather from the Rio Grande to the St. Croix, and meet the enemy at any point. Build vessels with one inch free board and daring spirits will come to the front and take them to sea as they did eighteen years ago. But that does not prove it to be advisable. *C'est magnifique,mais ce n'est pas la guerre.* Our vessels may be needed to patrol the coast, or guard a port; they may be called upon to carry the war into Africa, if only to the extent of making a dash at some of those outlying ports that menace us in the southeast, or northeast; or their presence may, in the distant future, be required at the isthmus. Whatever be the duty allotted, they should be of such build as to leave port under any circumstances, weather a November gale, and meet the enemy on fair terms.

One great peculiarity in the formation of our coasts is most puzzling to the naval architect in his desire to derive increased benefit from it. The shallowness of the water in many ports is in itself a powerful element of defense, limiting, as it does, the number of possible points of attack by heavy vessels. It is certainly incumbent upon us to increase to the utmost the value of that advantage by giving our vessels as light draught as possible, without detriment to the other more necessary qualities of seaworthiness and speed. The fate of the late Independencia, when decoyed into shoal water by the Covadonga, emphasizes this recommendation, as it would leave the lighter vessel freer to manœuvre in action, and enable her occasionally to cut off corners in chase or flight.

With this one exception we have to be guided by much the same rules as in other countries. In trying to meet all requirements a broad field is open and many competitors have entered the lists, but the victors have yet to be proclaimed. The prime requisites may be said to be: seaworthiness, or ability to keep the seas for an extended period in fair weather or foul; speed sufficient to be able to repair quickly to any threatened point and cope successfully with the enemy; great offensive power, vested judiciously in heavy guns, the most approved torpedoes, and the ram supplemented by facility of evolution; defensive power, obtained by heavy armor, a double bottom and numerous water-tight compartments; light draught to as great extent as possible without detriment to other qualities. The main difficulty of the problem is in the harmonizing of these desiderata. Even leaving aside the, to us, most important question of economy, we see that the size necessary to develop perfectly the first two qualities is restricted by the desired light draught.

Displacement is certainly necessary to give the vessel hold on the water, speed, ability to carry the guns, coal and armor, and enough free board to ensure safety. It does not seem easy to fulfil the conditions with less weight than five to six thousand tons, which may seem large to our legislative and appropriating body, but is inconsiderable when compared with the vessels we may be called upon to meet.

Selection of the material for construction has of course an important bearing upon the problem, as a decrease in the weight of the hull will admit of having a less displacement or of increasing the coal supply. The art of working steel has not yet reached perfection, especially in this country, and we may not yet be able to effect the saving of twenty per cent. in the weight of the hull that is claimed by the use of that metal in lieu of iron. For the frame it is unquestion-

ably well adapted, and steel girders can be manufactured perfectly well in America. As regards the skin plating there is perhaps room for discussion, although it has been successfully tried in England, and will without doubt eventually supersede iron entirely. Pending the development of that industry it is advisable to use steel only for the frames. By accepting iron for the skin we err on the safe side in the matter of weight, and if able finally to substitute steel we will simply gain a few more tons of coal.

In these brief remarks on the material best adapted to the construction of armored vessels, wood has been entirely eschewed, and it seems hardly necessary to prepare arguments against the use of that material. In cruisers for the high seas there may possibly be some differences of opinion, but even our limited experience on this side of the Atlantic, the necessity that we have been under of reconstructing our wood-built iron clads, makes it needless to refer to more extended facts and figures. In the design of an armored vessel for our particular service we would even discard the wood and copper sheathing over the bottom. The general advantages of that species of protection against fouling are of course well known to all, as well as the disadvantages. In the special case under consideration, the desirability of limiting the draught, and the possession of fresh water rivers, where the vessels could remain the greater part of the time, seem rather to indicate the propriety of trusting to anti-fouling composition on the bare iron, and save the six per cent. additional weight of hull entailed by the wood sheathing.

Almost all admiralties have recognized the necessity of sea-worthiness, and therefore, of a considerable size. In this, also, as in all competitions for supremacy of any kind, an extreme has been reached by some of the contestants, and, having swelled the weight of war vessels to fourteen thousand tons, the tide will probably slack in that direction, and resume the more normal level indicated by the Agamemnon, Richelieu, *et al.*

Apart from the question of size, the divergence of opinions is still wide in regard to the protection of water-line and battery, shape of the hull and relative value of different weapons of attack. In England after many experiments and changes the revolving turret system has prevailed, supplemented by protection of only the central portion of the ship. The French seem wedded to the open-top turrets supplemented by complete water-line protection. The Russian fleet comprises a formidable belted turret vessel without a projecting ram. The fact of

the turrets having been taken out of another vessel of the Imperial fleet, in consequence of the disaster that befell the Captain, bespeaks a lessened confidence in that system, while the conduct at sea of the Czar's new "yacht" was, in the opinion of Sir E. J. Reed, "full of significance as regards the possible steadiness of gun-platforms in ships of war." Protection for the battery and complete exposure of the water-line, after passing through various stages in the Inflexible and Duilio, have finally reached a maximum in the Italia, which vessel in action will be not unlike a man facing a north wind with a fur coat and bare legs. In addition to these special features, we see hosts of casemate and central-citadel vessels in various parts of the world.

Each nation, it is presumed, has faith in the type it has selected, but that faith is truly "the substance of things hoped for, the evidence of things not seen." When the crash comes in European politics, that has been predicted for so long, some valuable lessons may perhaps be drawn. Practical experience in modern naval warfare has so far been scarce. As far back as 1866, in the Donnybrook Fair engagement off the island of Lissa, the difficulty was demonstrated of successfully ramming an enemy in motion. The same difficulty has been experienced on more than one occasion within the last four years, off the South American coast. On the other hand the destruction of the Rè d'Italia is not needed to illustrate the tremendous power of offence centred in the ram. The frequently unavailing efforts made by vessels of the same fleet to avoid annihilating each other by the involuntary use of that weapon, are but too eloquent.

Various deductions have been drawn in the armor question from the accounts of the Huascar's last struggle in Peruvian hands. One point certainly seems to be decided, and that is that armor, if not thick enough to keep projectiles out had better be abandoned where men are stationed, for it only serves to explode the shells which might otherwise merely pass through injuring only what they struck. The "*débris*" of the guns' crews found in the Huascar's turret, to borrow a graphic expression from a paper in the United Service, bore ghastly testimony to that fact and to the terrible localization of shell effect in such confined space. One great advantage that the Chilian vessels had over their plucky antagonist was in their ability to command all points of the horizon with their guns, emphasizing a need that had long been appreciated.

As a nation we are fond of our monitors, and have had faith in them since that memorable day in March, 1862, when Lieutenant Worden led

their pioneer to victory. And it is not without pardonable pride that we see the main features of the type accepted by the leading maritime nations, after some years of doubt. But we must remember that while we have been lying on our oars and resting after our great struggle, our trans-Atlantic cousins and other friends have been hard at work, and, by incessant study, research and experiment, have so improved upon our crude idea as to leave it barely recognisable in its reproductions. Having started the ball ourselves, and allowed others to keep it rolling to what must be well nigh the end of its course, we may now with good grace look about us and adopt ideas pertinent to this new iron age.

The advantages of the revolving turret system are the most complete protection of men and guns with a minimum weight, the self-support due to a circular form, the ability to fire toward every point of the horizon, the smallness of the target and rareness of its being struck with direct impact. This latter quality was the very *raison d' être* of the monitors.

As before stated in this essay, the insuperable objections to these as they are now built, are the insufficiency of freeboard, which causes a very small reserve of buoyancy and inability to use the guns in a moderately heavy sea; insufficient thickness of protective metal; insufficient weight of battery. That these last two defects were well appreciated by the boards of officers that examined the plans of the Terror, Amphitrite, Monadnock, and Puritan, was shown in their recommendations that a greater thickness of compound armor be given them, and that heavy rifles be substituted for their smooth bore guns. Carrying out these necessary recommendations will unfortunately lead to an increase of draught and displacement and decrease in speed and freeboard. The latter will be reduced to two and a half feet. That is not enough either for safety or ability to fight at sea. The same smallness of target offered by vital parts may be retained with a much greater freeboard. Protect the water-line, machinery, and guns, and the rest of the ship may be shot away without affecting the issue of the fight. By raising the turrets so as to fire from ten to twelve feet above water, the body of the vessel may be brought up correspondingly higher, greater safety insured, and comfortable quarters provided the officers and crew. To avoid carrying the side armor up high enough to protect the bases of the raised turrets, recourse has been had to a middle breastwork in several most formidable European vessels, and this plan seems to combine more good qualities than any other for a displacement of five thousand to six thousand tons.

With the preceding remarks in view we submit the following design for an armored vessel best suited to the present needs of the United States. The calculations are by approximate formulæ. More accurate computations may be made on preparation of the plans and slight alterations made when necessary.

In general terms the vessel we propose is a breastwork monitor. The lower body is protected by heavy armor from just above the water-line to five feet below, and is covered by a plated deck. The sides then rise to a height of seven feet fore and aft, having the shape and external appearance of an ordinary vessel. Within this hull a breastwork rises in the middle to the same height as the sides above the armored deck, enclosing the smoke stack, ventilators and two turrets, one at each extremity. These turrets are then seven feet above water and the guns about twelve feet, and the horizon will be swept by their fire as in our monitors. The bow will end in a spur supported and protected by the side armor, which will be brought down over it with a diminished thickness. The steel deck will also be sloped down to it for additional support and to afford protection against a raking fire from forward. The propulsion will be by steam entirely, and applied by twin screws so as to ensure rapidity of evolution. Speed, thirteen knots. Dimensions and other details are as follows:

Length between perpendiculars,	270 feet.
Extreme breadth,	60 "
Mean draught,	17 "
Displacement,	5,508 tons.
Indicated horse power,	4,030
Estimated speed,	13 knots.
Coal supply,	480 tons.
Engines,	Compound.
Screws,	Twin.
Ten-inch breech loading rifles, (or larger.)	Four.
Reserve of buoyancy, (about)	44 per cent.

The side armor consists of a middle belt one hundred and sixty feet long, from three inches above water to five feet below; thickness at top ten inches, tapering to six at the bottom. Forward and aft of this the thickness diminishes to four inches at the top and three inches below, coming down forward and covering the ram with a thickness of two inches. The upper edge of the forward and after belts also drops to the water line. The backing up of the side armor to be of Georgia pine, ten inches thick at the middle belt and seven inches for the rest. A two

and a half inch steel deck lies flush with the upper edge of side armor, covered with three inch planking. Forward this deck runs down to near the point of the ram, which protrudes six feet at eight feet under water; aft it also slopes down to three feet under water.

The breastwork, amidships, is one hundred and forty feet long and seven feet high above the steel deck. The width will be thirty four feet, external dimension, which leaves a gangway on each side, of about twelve feet. The armor plating on this breastwork is twelve inches, backed by ten inches of Georgia pine. The main deck within it is not plated, but the deck covering will be of steel two inches thick, and will form the glacis for the bases of the turrets.

These, rising from just within the circular ends of the breastwork, are nine feet high, twenty eight feet in exterior diameter, and mailed with twelve inches of armor with an equal thickness of wooden backing (pine). On top the forward turret is the pilot-house, eight feet in exterior diameter, seven feet high, with ten inches armor, and a half-inch iron mantlet.

The smokestack will be clad with ten inches of armor for a height of six feet above the breastwork, or thirteen feet from the water; and an air duct, one foot interior diameter, will be similarly protected to a height of four feet.

All armor will be compound, iron with about one-third the total thickness of steel facing. The only exception is the deck, which is wholly of steel.

The weights carried are approximately as follows:

Hull (steel frames, and iron skin below water)	1,653	tons.
Battery (four 25½ ton guns,)	102	"
Ordnance stores (ammunition, gun carriages and equipments,)	135	"
Engines and boilers, including water,	825	"
Side armor.	345	"
Armored breastwork,	740	"
" deck.	540	"
" turrets and pilot-house,	395	"
Wood backing and bolts,	90	"
Armored smokestack and air-duct,	50	"
Coal,	480	"
Anchors and chains, crew, effects and provisions, etc.,	150	"
	5,505	

A displacement of five thousand five hundred tons was not arbitrarily taken, but is the least with which it is possible to satisfy imperative conditions. Calculations for a less weight were commenced, and it was found necessary to increase the size until that figure was reached. Seventy per cent. was adopted as the coëfficient of fineness of the hull, which will be very slightly less full than our recently built monitors, but rather more so than the iron-clads recently built abroad. The individual tastes of nations in this matter seem very apparent;

Italia,	.591	Inflexible .	.679
Duilio,	.637	Dreadnaught,	.697
Friedland.	.644	Miantonomoh,	.713
Amiral Duperré.	.656	Puritan,	.718

When, as in our case, it is strongly desirable to keep the draught within certain limits, some sacrifice has to be made in fineness of underwater body, for the displacement cannot be made up by length and breadth. There is a limit to the proportions of beam to draught for a vessel destined to see bad weather. The greatest innovation in that respect, the Livadia, may not yet be taken as proof positive of a successful idea. That she suffered no grave injury in her stormy trial is a notable tribute to the skill of the Clyde shipwrights, while the pounding of the waves on the bottom spoke loudly in condemnation of the principle as applied to sea-going ships.

In regard to the breastwork, there would undoubtedly be advantage in having it rise in continuation of the side-armor, as in the Dreadnaught. But the increase of weight would be such as to demand a greater displacement, with the inconveniences of greater cost and heavier draught.

Just a few details will give a sufficiently accurate idea of what we wish to produce.

The vessel will be built of steel with an iron skin, and will have a double bottom. One longitudinal and seven transverse water-tight bulk-heads will extend from the outer skin up to the deck at the water-line. These main compartments will be subdivided, as far as practicable, into a number of minor ones, also water-tight, and all of them, including the cells of the double bottom, will be provided with pipes to flood or free them as may be desired. There will be no overhang, for the reason that if broad enough to afford protection against ramming, it might prove a fruitful source of injury in a sea way.

The superstructure is not intended to contribute to the rigidity of

the hull, but must be made of such strength as to withstand the shock of the heaviest seas. Sharpshooters and the machine guns' crews will probably be stationed there in action, but the majority of the crew would, of course, be in the turrets and fire and engine rooms. A hand-rail will be fitted on deck, to unship easily and drop flat inboard.

The coal supply, limited to four hundred and eighty tons, will permit of none but compound engines. It is estimated by a liberal allowance (two and a half pounds per I. H. P. per hour) that that amount of fuel will drive her for a little over four days at thirteen knots. At the rate of ten knots an hour, it should last about ten days or twenty-four hundred miles; at eight knots, nineteen days or about thirty six hundred miles. A larger supply of coal would involve too great sacrifices in other points. A perfect ship of war is a practical impossibility. The one just described, under certain circumstances will labor under disadvantages; but, regard being had to all possible contingencies, we present the type as the most desirable for our navy.

CRUISERS.

In the design and construction of cruising vessels questions arise differing widely from those just discussed.

The contrariety of opinions formed and expressed in regard to the type best suited to our present needs are due to the varied conceptions of a cruiser's duty. In times of peace, men-of-war police the sea, execute surveys, and constitute schools of training for officers and men. But as these general duties can always be performed by whatever type may be selected, the whole matter hinges upon the question as to what service will be required of them when war, *ultima ratio regum*, follows unsuccessful arbitration. The various policies of attacking only the enemy's commerce, of resisting the advance of his iron clads, or of simply watching his cruisers, all have their advocates.

The object of a war is generally to enforce the cession of land, money, or a principle. Were we to devote our energies to preying on commercial vessels, we would undoubtedly make some valuable captures, which would make our enemy smart, but the smarting would be confined to the pockets of the few and the feelings of the many; the end of the war would be no nearer. As remarked by Admiral Jurien de la Gravière "the successful depredations of twenty Alabamas would not have delayed the fall of Richmond one day." We may add that one half that number combining to create a diversion or possibly raise,

for a few days, the blockade of one port, might have given a different coloring to some phases of the war.

A glance at the more practical points involved leads also to the conclusion that the policy of constructing war vessels simply to cope with merchantmen is erroneous. A high speed, equal to that of some of the trans-Atlantic packets, can only be attained by very large vessels. The horse power varying as the third, fourth, and fifth power of the speed, and as the two-thirds power of the displacement, it is the size of these vessels that makes their speed possible. It is their speed that makes their size profitable. A small vessel, however fast in smooth water, could never make much headway against seas that would only reduce the speed of an Arizona, Brittanic, or Orient to fifteen knots.

A perfectly efficient commerce-destroyer would therefore have to be very large and consequently very expensive, and, having less good fighting qualities, would have her sphere of additional usefulness limited to serving as a transport. A smaller and cheaper fighting ship, able to make only thirteen or fourteen knots in ordinary weather, instead of eighteen, could keep the seas for an extended period, possess handiness and a powerful battery, and also be able to overhaul ninety per cent. of the steamers now afloat. Moreover, those large and extraordinarily fast vessels, which, by the way, are mostly owned by one nation, whether employed as transports or supply vessels, would be apt to proceed under convoy if we were known to have vessels able to catch them. And if we had them the world would know it.

A modification of our present navigation laws would do much toward putting this question to rest. Far be it from our desire to discuss a matter that has assumed a political aspect of such serious import as to have been extensively shunned in the late presidential campaign. But were Congress to take the step of admitting foreign-built vessels to American registry, even under certain restrictions, not only would our mercantile steam marine receive a most invaluable impulse, but in the event of war our commerce destroyers, transports and despatch-boats would be in commission and practically equipped for this work, as they already are in other countries. With this in view, the thoughts of no one would revert to the idea of building men-of-war for other than fighting purposes.

By occupying the great maritime highways, encountering the enemy there, and striving to ensure safety for the carriers of our national and private property, the cruisers would perform the most important service that could be asked of them. They should have the power to es-

cape from a superior enemy, overhaul an inferior, and, with the help of Providence and stout hearts, capture or sink an equal.

How many of the vessels of other nations should be allowed to be superior is a practical question, depending upon the skill of our constructors and engineers and the liberality of Congress. Cruisers can be built carrying heavy armor and guns, and possessing great speed and enormous coal capacity. Such vessels could catch merchantmen and capture cruisers, but it would be using razors to cut blocks, a rather expensive waste of material. Most of the *soi disant* sea-going ironclads of Europe can undoubtedly keep the high seas, but not many will even be given that duty. It would cause their enemies too grim a satisfaction.

There are what are called armored cruisers, that is, vessels with sufficient thickness of metal at the water-line to keep out projectiles thrown by guns usually met with at sea. But their number is not great, and, according to present appearances, will not probably be increased. The expense of armoring vessels, combined with the detriment to other fighting qualities consequent upon the increased weight, is hardly commensurate with the advantages of so protecting them, if intended for work in distant seas. Devote the weight of the plating to a more powerful engine, greater coal supply and heavier battery, and the result would be a cheaper vessel, perhaps quite as useful. A vessel of this kind can successfully perform all services required of a cruiser, and, being less expensive, is in every respect of the type best suited to the probable wants of our navy.

As all the varied requirements of a war vessel conflict materially, both in the design and construction, it is a knotty point to decide to which should be given the greatest development. The prime elements of success are: speed, handiness, or ability to manœuvre rapidly under all circumstances of war, wind, or weather; power of self-support, that is to say, large capacity for stores, especially coal, and ability to economise the latter by the use of a full spread of canvas; the most effective offensive power. The words most effective are emphasized as in contradistinction to the often demanded greatest offensive power. The defense will rest solely in her power of offense, supplemented by perfected internal arrangements of water-tight compartments and placing the machinery as low as possible.

It seems rather unnecessary to discuss the importance of speed in naval battles. Suffice it here to weigh upon the facts that in fleet engagements the motions of all must be regulated by that of the slowest

vessel, either in proceeding to a point of attack, carrying out a plan of action, or frustrating an apparent plan of the enemy. In duels it is equally desirable, to risk or avoid action, to force action at whatever range may be most advantageous for a particularly constituted battery, or for extrication from an awkward position due to accident or ill-judged manœuvering.

The main difficulty encountered by the naval engineer in constructing engines of a required power is in the necessity of occupying as little space as possible in every direction, especially the vertical. Space is required for the crew, stores, ammunition, and coal, but paramount to all in an unarmored vessel is the absolute necessity of keeping the engines and boilers well below the water-line. This compactness is only obtained at the cost of a less economy in the application of power, which results in a greater consumption of fuel and the stowage of a correspondingly larger supply. In a heavy vessel not only is it a more simple problem to keep the machinery below water but the available space for coal is proportionately greater. The point to determine is that at which concessions to speed cease to be commensurate with the advantages.

For vessels whose occupation is simply in carrying cargoes between ports of a known depth, there now seems no immediate check to growth in size and engine power. The Great Eastern, prematurely built, will probably soon be matched, and many are the clairvoyants that tell of speeds to come far surpassing anything now known. With men-of-war it is different. If too large and unwieldy they lack that great quality of handiness so essential in action. If two expensive we cannot build enough, and would risk too many eggs in one basket.

In countries where the experiment has been tried, a very large size is looked upon with less favor now than at first. In this country, perhaps more than in others, does it seem desirable to fix a limit. Not all possible enemies have these ocean race boats, and, in the impossibility of foretelling from what point of the horizon the next war-cloud may approach, it behoves us so to organize and construct our modest fleet as to make the best of any circumstances that may arise.

Reviewing then our peculiar circumstances of smallness of appropriations and comparative isolation from scenes of diplomatic embroglio, we incline to making no greater concessions to speed than are necessary to ensure maintaining a steady rate of thirteen knots an hour for several days uninterruptedly, which will admit of perhaps fourteen over the measured mile. If in the space and for the same consumption

of fuel we can by mechanical skill obtain better results, so much the better. But that figure, while putting us at a very slight disadvantage if pitted against one or two particular nations, will leave us superior to the rest; and in the interim of peace our country will be better represented throughout the world, our commercial and other interests better served, the professional training of our *personnel* more surely perfected, and hydrographic work more extensively carried on by a certain number of such vessels than by a less number of faster ones.

Apart from the question of length and bulk, the handiness of a vessel is intimately connected and conflicting with the speed, in that it is best obtained by moderate proportions of length to breadth. In one direction the extreme ratio of eleven or twelve to one has been reached, in the other a nearly circular form still claims its advocates. Accepting the evidence of things seen we find proportions of 5 or 5½ to one have survived, as combining to the most satisfactory degree the two qualities we are discussing. With this shape a speed of fourteen knots can be obtained with a circle of evolution not disastrously great. Strength is also ensured, and good behavior in heavy weather.

In this connection it is important to decide upon the application of the propelling power. A twin-screw ship is well known to turn in a less space than a single screw. The farther advantages of the former lie in the facts that two engines in place of one would have to be disabled in order to cripple the ship; that the rudder and all the steering gear may be shot away, and the vessel be still quite manageable; and that the two screws give the best speed for the same expenditure of power. This last seems quite susceptible of explanation if we consider that the distance of the propellers from the run and deadwood allows them a freer supply of water and causes a less decrease of pressure under the stern, which is of course tantamount to a less increase of resistance under the bows. Taking the ratio of the indicated horse-power to the two-thirds power of the displacement as an index of the relative economy, Mr. W. H. White, in his Manual of Naval Architecture, states that "when steaming at a uniform rate of fourteen knots, the average ratio for the single-screw ships is about 17.5 as against 15.5 for the twin-screw ships, or about 11 per cent. in favor of the latter." The conclusion was arrived at after experiments carried on with vessels of the English navy, where even despatch-vessels are now being thus engined.

Over there also two-bladed propellers, capable of being lifted, have been successfully used, while in our service they seem to have lost

favor despite their many advantages. Whatever may be the merits of the case in single screw-ships, it is impossible, of course, with the double screws, to do better than let them revolve when under sail. But the good points cited above in favor of the latter, coupled with the freedom to have a longitudinal strengthening and water-tight bulkhead, ought surely to override the objections that they cannot be lifted and that they are somewhat more liable to injury from contact with wreckage or a friendly wharf. In action there is no question about it. The saving of perhaps fifty yards in the diameter of a circle of evolution may win the day, and we are not so rich as to afford to have one kind for service in peace, and another for fighting. A peace navy is an absurdity. All our vessels should be designed to give and take hard knocks, and the harder we give them the less hard we will get back. The twin-screw ship can unquestionably give harder knocks than the single screw.

The greater or less power of self-support at sea is in some respects a matter of detail rather than of type. Additional coal-bunkers may be put up at any time, regard being only had not to sink the vessel below her intended lines. If full-rigged, as all cruisers should be, so as to make good progress under sail, and to stay and to wear, it would simply lie with the commanding officer what top-hamper to strike in the event of encountering an enemy. For ordinary service full sail-power should be available, for the double purpose of effecting important economy and of affording instruction and exercise to the crew. A good man-of-war sailor is "handy" at anything, from a sail-needle to a 100-ton gun, and this is mainly due to his varied occupations and exercises. We should not lose sight of it in preparing his home. It is certainly noticeable, as a rule, that the most cheerful, contented, and healthy men are found in "smart" ships.

Finally come we to the interesting question of the most effective offensive power. In the selection of the battery we must again be guided by what service is expected of the ship. Armored vessels destined to fight walls of iron, stone, or earth must have heavy ordnance to accomplish anything. The guns of the Huascar in her engagement with the Chilian fleet were not any too powerful. But in that vessel's previous bout with the Shah and Amethyst, the same weight of metal vested in a greater number of smaller guns (protected from gatling fire) would have increased her chances of success.

In the absence of farther actual illustrations, let us suppose a vessel, T′, armored to fight the Trenton and precisely similar to her in point

of speed, size, and handiness, and carrying the same four 8-inch rifles forward and one aft, but with ten of our old 9-inch smooth bores in place of the remaining six rifles. On sighting her enemy T′ would immediately seek close quarters, and being of the same speed, could not be well denied it entirely. While approaching, her four rifles would match the Trenton's battery, and at close quarters the five nine-inch shell would have greater effect than the three eight-inch hurled at her. The greatest distance that the Trenton, by the best manœuvring, could refuse T′ would be the diameter of their circle of evolution. What that diameter is, is not exactly known to us, but it should not be over four hundred to four hundred and fifty yards, and at that range the greater number of larger though lighter shots would outweigh disadvantages incident upon the wind.

In this case it would seem that smooth bore guns would have the best of it. But in the impossibility of being confined to certain cases in war, it would be wrong to put any but rifled ordnance in a cruiser. Were T, armed with ten eighty-pdr rifles in place of the smooth bores, her efficiency for ordinary service would be greater, as she might have to do with a faster vessel, or with one lightly armored. But while the guns used in chase or retreat should be heavy so as to be effective at long range, it seems desirable for the general purposes and probable circumstances of a cruiser to multiply the number of broadside shots at the cost of weight in the projectile. This seems to have been recognised in arming one of the most powerful vessels now afloat. The Amiral Duperré carries fourteen 5½-inch rifles mounted in broadside, besides the 13½-inch barbette guns. The vulnerability at the water-line of some recently built iron-clads may farther point the moral of that tale, and peppering the hull with a number of small shell may some day put the saving power of cork to a severe test.

Whatever the calibre of the guns, they should load at the breech. Increased power and precision, as well as protection to the loaders, are arguments to which all ordnance officers, however conservative, have had to bow, silenced if not convinced.

What is sometimes considered a disadvantage in thus increasing the number of guns, is that it also increases the number of men needed to work them. In some vessels that certainly is a tenable position. In the breastwork monitor, propelled entirely by steam, armed with guns worked by hydraulic power, built and commissioned solely for offensive warfare against ships or forts, the crew should be reduced to a minimum.

In a cruiser, whose multifarious duties include the training of seamen, surveying, manning prizes and sending boat and landing parties to the shore, it ceases to be an objection, and assumes the character of a desideratum. The increase in the number of men on a gun deck would barely be sufficient to warrant fears of a slaughter, unless they are exposed to Gatling fire. The machine-guns of recent invention have practically sealed the doom of the wide pivot ports universally found in our vessels, and as emphatically point to the necessity of protecting the crews of broadside guns, as well as the officers on the bridge, from the fire out of the enemy's tops. In other words, a spar deck should be adopted whenever practicable, apart from the benefits of having room to work while exercising or clearing ship for action. With that and the ability to load at the breech instead of the muzzle, the gunners would be practically free from small iron annoyance. The commanding officers will have to be provided with rifle-proof screens or pilot houses on the bridge.

An additional weapon of offense is found in the ram. That method of attack is as old as the hills, and the weapon interferes less than any with other qualities. In view of the possibility of the enemy's being armored, or perhaps having an iron or steel deck just below the water-line, it is necessary to deliver the blow under water. Great length of spur seems undesirable because of its consequent weakness and liability to be wrenched off, and because it is not generally necessary to pierce far into the body. Should the rammed vessel have a double bottom, the inner skin will seldom be over three and a half feet from the outer; and a six foot spur would seem ample to do great injury, and can also be made very strong. Should she be armored under water a depth of eight feet will suffice to clear it.

As for torpedoes, after a life of one hundred and four years they are still said to be in their infancy. The Harvey has been given up in despair by its staunchest advocates. The spar-torpedo, occasionally terribly successful when fitted to a small vessel especially built for it, is but a cumbrous nuisance in a large ship, and, with gear shot away by Hotchkiss or Nordenfeldt guns, is apt to prove a dangerous ally. The safest weapon is that which is least apt to 'return to its fold.' The Whitehead now seems to give the fairest promise, although only a small percentage of its trials have resulted in injury to the object of its attentions. In the absence of proof we can but accept promises, and with submarine warfare in its present stage it is advisable to fit ocean cruisers with tubes for discharging the Whitehead torpedo.

The type and general features of the vessel being decided upon, one item remains to be considered, which, although not affecting her immediate behavior under fire, is most important in the one thing that touches us to the quick. That thing is economy. The item is the material of which she should be built. Wood, iron, or both? Which shall be used?

A glance at statistical tables of cost of repair will perhaps be a more forcible argument than any against the farther use of wood. Cheap vessels we certainly must have, and when, by the use of metal, cheapness may be obtained in association with equal or greater strength and greater lightness, building vessels of wood seems no longer defensible. The immensely strong hull of the Devastation weighs, including the superstructure, less than thirty one per cent of the displacement, while in some old wood built armored ships the weight of the hull exceeded the weight carried. In the modern swift cruiser class the figure is about the same in the two cases, owing to the additional weight of wooden sheathing.

In the matter of fostering and developing our home industries, we would be guided toward building our national vessels, or at least their frames, of iron and steel.

To go somewhat into details we find that the advantages of an iron hull over a wooden one are: cheapness of repair, greater durability, increased lightness combined with greater strength. Disadvantages: more easy penetration of the bottom on taking the ground, fouling, greater discomfort and unhealthiness in a tropical climate, the shattering effect of projectiles. The fouling is best prevented, and the inconvenience and expense of frequent docking saved, by sheathing in wood and coppering. This is, unfortunately, open to the objections of materially increasing the weight, and in case of injury to the bottom, of probably admitting contact or galvanic connection between the two metals, under circumstances that might forbid examination and remedy, on the other hand, that system of protection, when carried up above water has the double advantage of making the vessel more comfortable and more healthy in very high or very low latitudes, and of diminishing the dangerous splintering in action. Now that rifled ordnance is in general use, this last objection obtains to a much less extent than when the blows were from spherical shell moving with a lower velocity. But it is still a point of some importance, and is best met by spacing the frames and sheathing the plates.

On examination of these various pros and cons, it quickly becomes ev-

ident that all the advantages arise from the iron framing, and the inconvenience from the iron skin. This suggests a composite build.

The difficulty in properly fastening wood and iron, and the fear of not obtaining equal structural strength, lead to hesitation in clothing the frame in wood. These are practical questions of mechanical skill and may perchance be solved satisfactorily. The expressions "good enough," "strong enough" have a slouchy sound, seeming to indicate a sort of careless self-sufficiency. But that such a thing is possible as to make a framework stronger than is necessary has been proven, notably in the original design of the marine ram proposed by Admiral Ammen. In that case eight longitudinal girders were discarded as superfluous.

The tensile and compressive strength of wood being so inferior to that of iron, and the effective sectional area (after driving bolts and rivets) of the planking being only about five-sevenths as great in proportion as that of the plating, there is no disputing that the former will contribute less than the latter to the general strength of the fabric. In vessels where the proportions of length to breadth are greater, and the natural strength consequently less than in the case under discussion, and when the number of horses' power required is nearly double the number of tons displacement, every detail must look to rigidity and strength of hull. According to recent reports, even the steel frames and skin of the Iris seem none too strong to stand the vibration caused by the development of such immense power. Not aiming at her marvellous speed, however, we will find a more moderate strength ample for our purposes, with the help of a longitudinal bulkhead, longitudinal frames, bilge kelsons, and string and shelf pieces, it seems quite possible to produce a rigidity equal to any demand in a vessel of the dimensions and speed here proposed. When, as stated by Mr. Reed, late Chief Constructor of the British Navy, a saving of one hundred and fifty tons weight could be effected in a mail steamer of twenty-seven hundred tons, by making the transverse frames subordinate to the longitudinal, it is certainly rational to expect, by developing longitudinal frames in combination with the ordinary transverse ones, an increase of strength sufficient to supply that of the iron skin.

By this composite build, then, we can secure economy and facility of repair, less liability to injury from grounding, less deadly effect from splinters on being struck in action, and, thanks to the non-conducting properties of wood, less cold in high latitudes and less heat in the tropics. The danger of imperfect insulation between the iron and

the outside copper is not so great as in the first days of this style of construction, and certainly less so than when an immense surface of plating lies hid. The experiment tried in a vessel recently built for U. S. Fish Commission, if successful, will show that by the use of rubber washers driven over the bolt-heads, one course of planking may be made effective. But whether one, two or three courses be laid, whether they be worked longitudinally, diagonally, or vertically, whether muntz metal or iron bolts be used, and whether the outside sheathing be of copper or zinc, are minor points hardly within the limits of our discussion.

Suffice it to present the following broad features of the cruiser suited to our present, and probable future, needs.

A composite-built hull, (iron, or steel frames, keelson and keel-plate, with wood keel and planking) with proportions of about five and a half to one of length to breadth, and laid down for a speed of fourteen knots. Displacement twenty-five hundred tons, or approximately that of the Benicia class, but with lines similar to the Swatara, which vessel has not her superior in behavior at sea. The engines to be compound, of sufficient power to drive the vessel fourteen knots an hour under favorable circumstances. They will be applied to twin screws, and it is recommended that they be provided with valves to admit of working them as simple engines, if desired, and that they have independent circulating pumps. Apart from their superiority *per se* there is a feature of these independent pumps that is well worth considering, viz: that they do not betray to an outsider the fact of the engine's having stopped or started, as is done by the out board delivery when they are connected with the engines and have to stop or start with them. On more than one occasion in our experience has the avoidance of collision been facilitated by thus knowing that the stranger had stopped. Desirable in a friendly meeting this would be the opposite in action, and it might be important to deny the enemy a knowledge which would dictate the way to put the helm in an attempt to ram.

The boilers should be fitted with automatic valves to prevent the flow of steam from one to another in case of injury by shot or otherwise. They must also be protected by coal laterally and from forward.

The battery, which is to be on a covered deck, will consist of breech-loading rifles;—two eight-inch in chase, and one of the same calibre aft, with eight six-inch in broadside. These, of course, will be supplemented by the usual machine guns for use aloft or on the rail.

The ram will not be a spur pointing forward from the body of the

vessel, but of such shape that the lines of the vessel will commence at its forward edge, as nearly as practicable, for the sake of strength and buoyancy. Above water the bows will continue to recede slightly as in the Alarm, though to a less extent, so as to throw the weight of the bow-chasers aft, and make the vessel lift more easily and ride drier in a head sea. The point of the ram should be about ten feet under water and eight feet forward. At the stern appearances must be sacrificed, and the counter brought well down so as to conceal if not protect the rudder-head.

In the matter of sails, a full ship-rig to royals should always be given a vessel of this size. The head-booms must be arranged to rig in and out easily.

Without going into minute details of what longitudinal framing is desirable, we will simply weigh upon the propriety of having stringer-plates or shelf-pieces on all the decks, but more especially on the berth deck where the greater force of a blow is apt to come in collision. In the absence of a heavy iron deck, which is one of the best protections against ramming, its properties would be partially found in a broad shelf piece just below the water line. One longitudinal bulkhead, extending from the stern port to the point of the ram, and seven or eight transverse, all water-tight, will add greatly to the structural strength and permit of isolating damages received. Farther water-tight subdivision in coal bunkers and elsewhere should be effected when practicable.

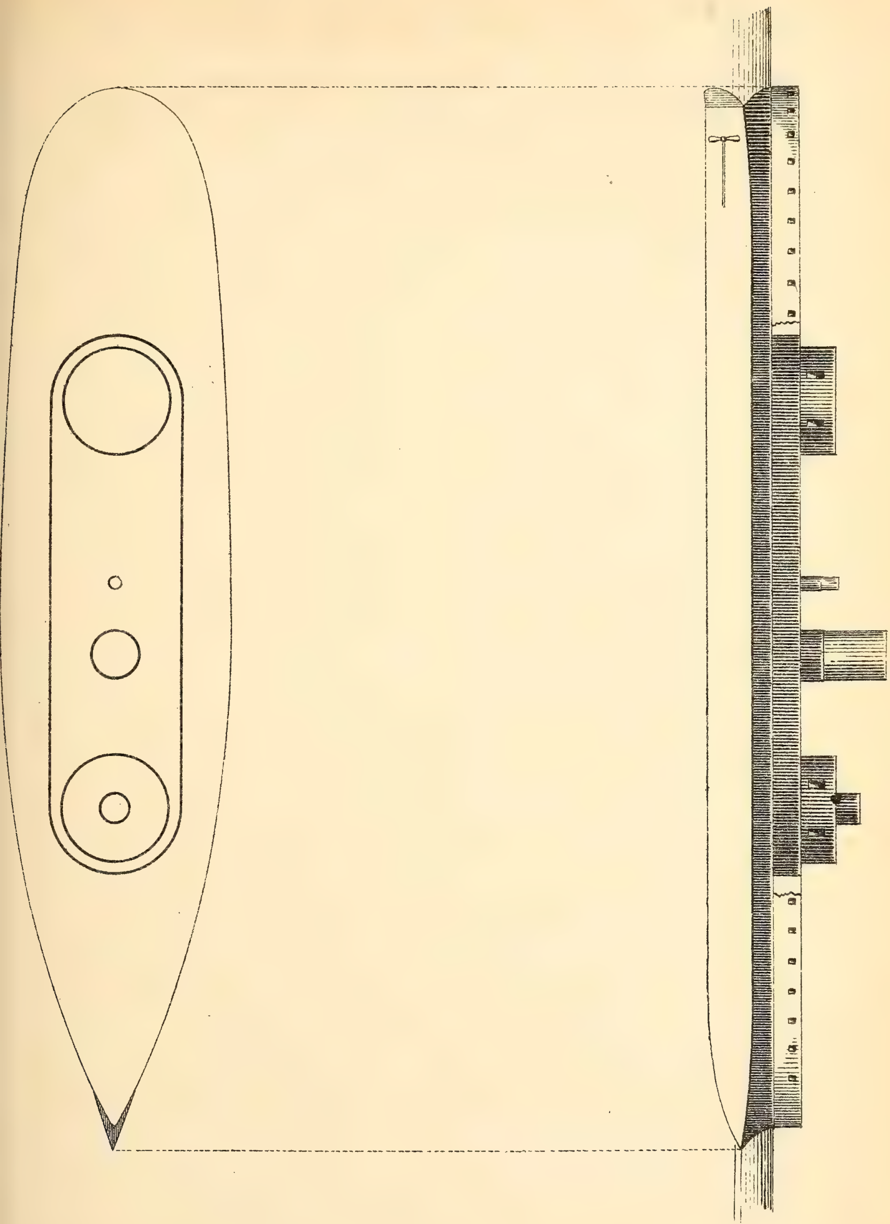
Smaller vessels than what we have proposed may be needed for special duty of various kinds, but they should constitute a separate class. The cruiser for ordinary service in peace or war should not be tampered with, nor attempts made to include such special work in their capabilities.

It would be well to build one in every four or five of a larger size, like the Trenton, to replace gradually our present flagships. These would be on the same general model, possessing perhaps a little better speed, and armed like the Trenton with the exception of the six eight-inch broadside guns, for which would be substituted ten six-inch.

The salient points of the type given, to which objection might be made, are the limited speed (probably thirteen knots for a steady rate at sea) and the light battery. It may seem that a faster steamer armed with a few guns of heavier calibre, would have our vessel at its mercy by keeping at such a distance as to leave only the heavy guns available. That is not so easy to do if our vessel keeps heading

straight for her adversary. Moreover when the distance of the target is greater than the ordinary range of our eight-inch rifles, the probability of hitting is very small. Still, let us suppose that the superiority of the faster vessel's range is a thousand yards. If the other keeps steering towards her, she must take to her heels to maintain a proper distance, and either be content with using her stern gun, or else make an occasional sheer to bring her broadside to bear. In the days of sailing ships the advisability of luffing to deliver a broadside in chase was a mooted point, even when the number of guns was so great, and the target, including a broad expanse of spars and sails, so tempting. Much less would it seem advantageous where the target is so small, the number of guns so much less, and the distance so much greater. In the case supposed the slower vessel advancing steadily at the rate of thirteen knots would make the thousand yards in less than two and a half minutes, which is not much time to bring by, point and fire at the bows of a vessel nearly two miles off, and head away again. The thirteen knot vessel would be pretty sure to get within the range of her two bow guns, and would then have the broadside of her antagonist for a target and the advantage of firing in a direction least influenced by the roll.

It is practically impossible for a vessel having even two knots better speed to remain out of range of light guns, and yet, by estimating the distance, be within the range of her own heavier ones. Advantage in speed, if not nullified by unwieldiness will certainly promote successful manœuvring when engaged, and our cruiser may not pretend to withstand everything afloat. Skirmishers do not generally attack forts, though the necessity of that deployment is none the less recognised in military operations. Our breastwork monitor, too, may be overmatched by a leviathan clad in two and three feet of iron and steel, and hurling projectiles that weigh a ton or more. Both might succumb in an unequal contest. But they will rarely have such odds. And it is thought that the one and the other will give a good account of themselves under any circumstances, for the spirits that move them will have recognised the truth of the motto that guided us in attempting this essay.



PROFESSIONAL NOTES.

These Articles have not been read before the Institute, but are inserted by direction of the Executive Committee.

REPAIRING A BROKEN CRANK WITH WIRE ROPE.

The following description of the temporary repairs made to the broken cranks of the U. S. S. Pensacola, by Passed Assistant Engineer Geo. W. Stivers, U. S. N., is interesting in showing what may be done with wire rope in the way of repairs on shipboard.

"The after crank of the forward engine only is shown, this one having been broken entirely across, but the plan adopted in banding both cranks of the after engine, which were broken nearly across, was precisely the same. The crank shaft and cranks were in one solid forging, and the fractures, were directly across the bodies of the cranks, between the crank pins and the shaft, as if following the plane of contact of fagots used in building up the cranks in the smithery.

For several months the existence of a very slight crack in the after crank of the forward engine was known, but frequent examinations failed to show any extension, and it was considered simply a surface flaw of no great consequence.

At about 5 P. M., June 18th, the ship being on her way from San Francisco to Puget Sound, it was found that this crack was extending rapidly. The weather was fine, sea smooth, and, with square sails set, the engines were slowed down, while preparations were made to strengthen the crank by temporary bands, so as to reach Victoria where it was expected that a heavy band could be forged and shrunk on.

The only iron that could be worked on board ship was a piece three and seven-eighths inches wide and three-fourths inch thick, and it was proposed to make of this two bands to embrace the crank side by side and to be set up by two 1-inch bolts on each side, passing through lugs formed by bending up and thickening the ends. The strength of the bands as straps was therefore only that of two 1-inch bolts, and their utter insufficiency was evident.

At about nine o'clock that night the crank had broken entirely across, but as the two parts moved together as usual, the irregular surfaces of the break and the long forward journal preventing their separation, the engines were kept slowly revolving until noon of the next day, when the plan of iron bands was abandoned, before being carried out, in favor of that which I had proposed, and the engines were stopped to allow its application.

Ten gutter pieces or shoes were made of an old iron grating and placed equidistant about the crank in order to keep the bottom turns of wire rope from spreading apart, when the riding turns came to be put on over them. The shoe at the extreme end and that on the butt of the crank only were secured in place by a small bolt through the center, the other shoe being held in proper position by hand until bound by the first turn or two of rope. Into the hubs of the crank a bolt one inch in diameter was tapped, to which the end of the rope was secured, and the work of wrapping the crank consisted simply in passing the wire rope continuously around the crank, hauling each turn taut by means of a heavy deck tackle passing down through the engine room hatch, and seizing each turn securely to the one immediately preceding it before slacking off the tackle. It was estimated that a tightening pull of about two tons was brought on each turn of rope, and the seizing of the separate turns having been done very expertly, there was no slacking back of the wire rope during the progress of the whole work.

In this manner eleven turns of the rope were put around the crank side by side, just filling up the space between the jaws of the shoes, then over these were put the riding turns, and over these again nine more riding turns, making altogether thirty turns of wire rope encircling the crank. The finishing end was simply passed around the banding at one of the shoes and stopped as shown in the sketch.

The wire rope used in this work was of nine-sixteenths inch diameter, consisting of five strands of seventeen wires each, arranged about a central hemp core of three-sixteenths inch diameter, the wires being of number nineteen wire guage. The work of banding this crank was completed in seven hours, and just as it was finished, it was found that both the cranks of the after engine were broken nearly across, the cracks extending entirely through each crank and to within about an inch of each side in about the same direction and relative position as in the forward crank. This discovery caused the abandonment of the attempt to reach Victoria, the ship was headed to the southward with

the intention of returning as best we could to San Francisco under sail, and, the banding of the forward crank having been so satisfactorily accomplished, it was decided to strengthen the after crank in the same manner, so that the engines might be used in case of emergency.

This was done and, when about two hundred miles from San Francisco, the wind blowing lightly from ahead and sails being useless, the engines were started and worked continuously without stopping for over forty-five hours until the anchor was dropped in the harbor of San Francisco. During this time forty-five thousand eight hundred and thirty-five revolutions were made, an average of 16.85 revolutions per minute, and an average speed made of 4.41 knots per hour under steam alone. The next day the ship was steamed up to the Mare Island Navy Yard, 26 miles from San Francisco, the engines being stopped and started seventeen times during the run to allow target practice, and upon arrival at the yard the rope banding was found to be as firm and unyielding as when first put on the cranks.

The speed at which the engines were run with these fractured cranks was low, for the weather was fine and no necessity required the taking of the least risk; the initial pressure above zero on the pistons was twenty pounds, cutting off at nine inches, there being two cylinders sixty inches diameter and thirty-six inches stroke; yet it is evident from a calculation of the strength of the banding on the extreme after crank which transmits the power of both engines and which would have been strengthened if more wire rope had been at hand, that a considerably greater speed could have been safely attained.

The gutter pieces or shoes were, it will be seen, indispensable to the successful application of the wire rope banding, for they prevented the first course of rope from spreading under the pressure of the riding turns; they allowed the driving of iron wedges beneath them without injury to the rope, in case it should become slack and require tightening and they permitted the passing of the end of the rope between the crank and the whole banding so as to secure it firmly.

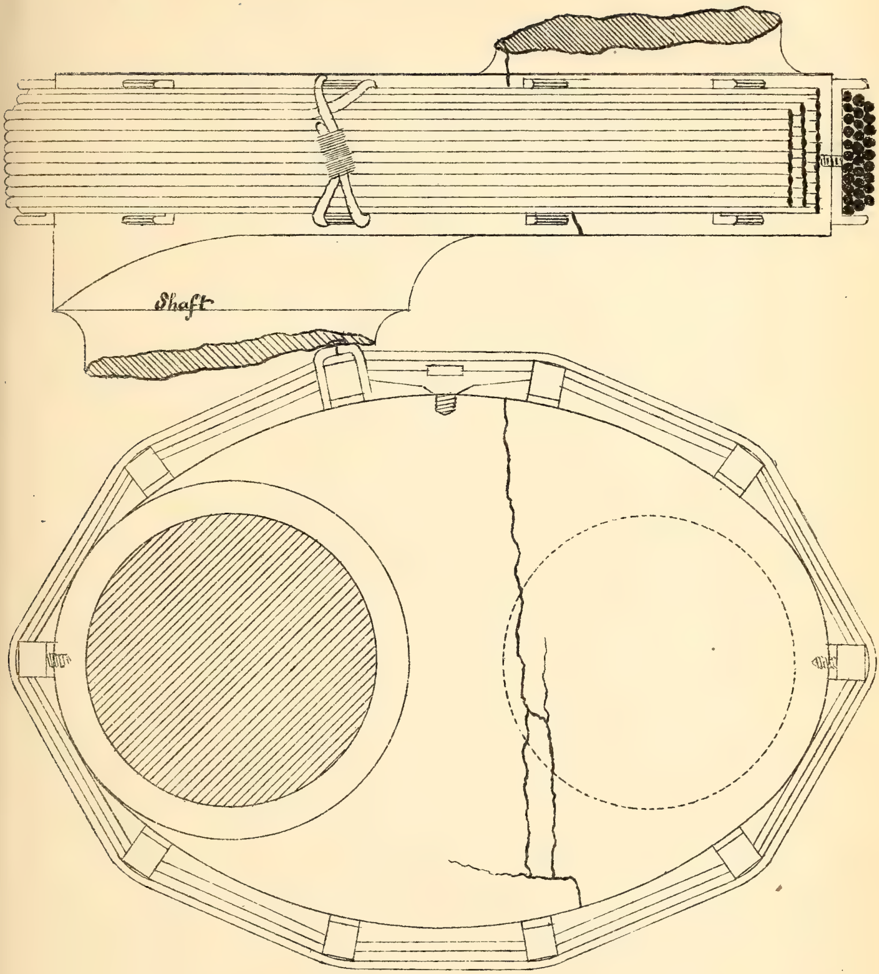
I expected that the wire rope would, in a short time stretch, and had intended therefore to first drive wedges under each shoe, nipping the ends over the edge of the crank, and then to drive all around, under the rope banding, dry pine wedges which would be swelled by the water used on the crank pins, but there was no necessity for any wedging up whatever, and perhaps would not have been, had the engines been in operation a much longer time than they were. The shape of these cranks made the application of the banding quite a simple matter, but

I apprehend it would not be very difficult to adapt such a system of wrapping with wire rope to a crank of any shape whatever.

I do not think the idea has occurred to engineers generally that they have in wire rope such a ready and effective means of temporarily repairing damages to engines at sea. Many repairs that are now made with straps or bands hastily constructed under the disadvantages always attending smith's work on board ship can be much more quickly and easily made by a few turns of wire rope. The ease and facility with which repairs can be made with wire rope commend it to engineers and steam ship owners as a part of the necessary outfit for steamships. This material may yet be the means of repairing the broken shaft of a steamer, so that she will be able to steam into port at a moderate rate of speed.

In the case of repairs to a broken shaft, the ends of the rope could be secured to the back of square pieces of iron, with holes to pass the rope through;—passing the turns around the shaft, and securing the other end to the other part of the shaft in a like manner; the square pieces to be recessed into the shaft as a key and secured by tap bolts to hold them securely to the shaft; for backing, there must be layers of rope wound around the shaft in the opposite direction.

J. C. Kafer, P. A. Engnr., U. S. N.


Shaft

BOOK NOTICES.

Notices and reviews of professional publications may be inserted under this heading, provided a copy to be deposited in the library of the Institute is sent to the Corresponding Secretary. All reviews must be signed by the reviewer.

NAUTISCH--TECHNISCHES WÖRTERBUCH DER MARINE, *by P. E. Dabovich.* Published by the editors of the *Mittheilungen aus dem Gebiete des Seewesens,* Pola, Austria.

The Institute is indebted to the courtesy of the publishers for a copy of the sixth part of this nautical technical dictionary. According to the prospectus the first volume is to give the terms in German, Italian, French and English, and also in Italian, German, French and English. It is to be issued in about twelve parts (Lieferung) of eighty pages each at a cost of two marks each. In the preparation of this dictionary the latest naval works and the official publications of the naval departments of these countries have been consulted. In English, for example, some of the authorities cited are Capt. Nares on orthography of Naval terms; Reed, Rankin and White on naval architecture and machinery; Lloyd's Rules etc. The German and Italian words are introduced in alphabetical order and are distiguished from each other by the type, full-faced type being used for the German words and italics for the Italian. The typographical execution is excellent, the paper being good, the type clear and the form of the volume convenient. The field which this dictionary seeks to cover being comparatively narrow it admits of greater fullness, and on comparison we find that while this work devotes seventy-nine pages to words from El to Fr, von Albert's Technologisches Worten-buch gives but forty-three pages of the same size to this division. The rules of the road are given at length under their appropriate heads. It would be manifestly unfair for us to pass judgment upon the whole work from the part before us, yet we cannot refrain from calling attention to the fact that many of the English renderings while literal are not idiomatic, that numerous errors in orthography are committed, and that occasionally French words are used in English

sentences. Some examples of the first are der Hochofenguss rendered *Iron cast out of the high-furnace*; der verdächtige Gesundheitspass, *touched bill of health;* Fensterschiebe, *glass square*; Feuerwirkung, *performance of the fire*; die Eisentheile zur Leitung des Tauwerks, *iron works for leading the ropes*; and unter Hand fieren, *To ease off hand under hand.* Examples of the second errors are; *serge* of the cable; *afriction, pledgeds ; heckled and speckless.* As this work must be of value to all English speaking officers it is to be hoped that the future parts may be revised by some officers, whose mother tongue is English, before publication.

ALMANACH FÜR DIE K. K. KRIEGS-MARINE, 1881. New series, 1st year. Published by the editors of the *Mittheilungen aus dem Gebiete des Seewesens; Pola.*

From the same source we have received a copy of this admirable little pocket book containing a register of the Austro-Hungarian navy, pay tables, extracts from the laws and regulations for the navy, tables, a formula for use in navigation and descriptions of the methods employed, useful tables upon the consumption of coal, the calorific power of coal, strength of material, dimensions of ships and machinery, electrical tables, tables of time, money, and measures, tables of the navies of the world and their armaments and armor, and many other useful tables making it a valuable pocket compendium. It is amusing to find at the end of the table devoted to the United States Navy, "that all data upon the American Navy is little to be depended on."

C. E. MONROE, PROF. U. S. N. A.

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FEBRUARY, 1881. The Atalanta report. The Russian Imperial yacht Livadia. Soldiers and sailors and their wills. *Editorial and critical notices.*

MARCH, 1881. The condition of our fighting forces, with suggestions. H. M. S. Resolute, a true story of the Arctic Regions. Shipping bounties. *Editorial Notes.*

COMPTES RENDUS. VOL. XCI, NO, 16. Admiral Mouchez commends the accuracy of Lt. Comdrs. Green and Davis, in their determinations, by telegraph, of some of the priucipal longitudes on the coast of Brazil. He was himself charged, in 1860, with the task of determining the hydrography of Brazil and La Plata. In the performance of his duties he made a large number of astronomical observations, which accorded so closely with previous records that he affirmed in his report that the longitudes were known with nearly as great accuracy as those of the great observatories of Europe. The French astronomers, however, discredited his results and adopted values about 30 seconds greater. The American observers have fully confirmed Moucez's assertions, showing that his greatest error was only 2.34 seconds, and in one case the error was only five-eighths of a second. Errors of from two to four seconds have been recently detected in the longitudes of some of the European ports. These comparisons also show the great precision with which longitudes can be ascertained by chronometers, when their rates are properly verified at the end of every voyage.

VOL. XCII. NO. 8. THE SOLAR PARALLAX. M. Faye communicates to the French Academy of Sciences an interesting paper upon the state of our knowledge of the sun's parrallax. Remarking that there is no other constant in nature whose determination depends upon so large a number of independent results, he classifies the various values assigned for the sun's mean parrallax a follows:

Geometrical Methods 8.82″	8.85″ by Mars, (Cassini's method). Newcomb.
	8.78″ by Venus, 1769, (Halley's method.) Powalky.
	8.81″ by Venus, 1874, (Halley's method.) Tupman.
	8.87″ by Flora, (Galle's method.) Galle.
	8.79″ by Juno, (Galle's method). Lindsay.
Mechanical Methods 8.83″	8.81″ by the lunar inequality, (Laplace's methods). ——.
	8.85″ by the monthly equation of the earth. Leverrier.
	8.83″ by the perturbations of Mars and Venus. Leverrier.
Physical Methods 8.81″	8.799″ by the velocity of light (Fizeau's). Cornu.
	8.813″ " " (Foucault's method.) Michelson.

Faye concludes that the results obtained by the physical methods are more reliable than those obtained in any other way, and by adopting the results obtained by Master A. A. Michelson, U. S. N., in his determination of the velocity of light, the value of the solar parallax 8.813″ is now determined to within one hundredth of a second of arc.

EDINBURGH REVIEW. JAN. 1881. The Navies of the World.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION, NO. CVIII. (Naval Articles). The Nordenfelt machine guns (Palmcrantz's system.) *Occasional Papers.* On the several European Systems of Naval Education. Under the above title J. K. Laughton, R. N., Mathematical and Naval Instructor at the Royal Naval College reviews at length Prof. Soley's "Report on Foreign Systems of Naval Education." He says, "His investigations appear to have been thorough and searching, and the report which he rendered to the Secretary of the Navy, now published by order of the Senate of the United States, embodies more accurate and detailed information, as well as more intelligent criticism on the various systems of naval education, than has hitherto been rendered in any way availiable."

"Not unnaturally, the report begins with Great Britain; and, following carefully the several statements made as to matters of fact, we are struck with the remarkable accuracy of the whole: the very few errors that we have noticed are of the most trifling nature, entirely void of significance; and if we may take this first part as a guage of the merit of the other three, the work stands almost alone as an absolutely correct historical record. It is as such a gauge that we have used it. We do not propose to repeat here the minute details which Professor Soley has given of the English system of entry, of service, and of promotion; of education on board the "Britannia" in sea-going ships, and at the College at Greenwich. They cannot but be pretty well known to all readers of the Journal who are interested in the subject. But whilst thus omitting the facts, we think that the opinions which Mr. Soley has been led to form on the several points connected with our system are well worth reproducing, if only as the opinions of a singularly capable and well-informed foreigner free from the trammels of old custom and of national prejudice."

In a postscript Prof. Laughton notices the American system of education as deduced from the Official Reports of the Secretary of the U. S. Navy, from the Registers of the U. S. Naval Academy and from Prof. Soley's

Historical Sketch of the U. S. Naval Academy. His conclusions are "that the American system is singular in this; that nominations are given largely in excess of the requirements of the service; and that the nominees are ruthlessly thinned out by a test examination and a course of instruction beyond the capabilities of three-fourths of their number. Such a system must be exceedingly costly and excessively laborious; it must also tend to lower the standard not only of admission but of graduation; and though this latter—owing to the riper age of the cadets and the four years' close study at a college on shore—is somewhat higher than the obligatory course in our own Service, it would seem to compare unfavorably with that of either Germany or France. Whether a competitive examination for entry (as is held for the cadet-engineers), or for passing out, would not be more advantageous is a question which naturally occurs to us, but which probably political motives have led the American Representatives to answer in the negative. *Reviews and Book Notices.* "The War Ships and Navies of the World" by Chief Eng. J. W. King, U. S. N. "Navies of the World" by Lieut. E. W. Very, U. S. N. Mr. King is already known to English readers. Two years ago a volume by him on the 'War Ships of Europe,' was published in his own country and republished in this. His present work comprises a survey of every navy in the world. It is to a great extent composed of extracts from English newspapers such as the Times, Engineer, Broad Arrow, et cet. He has also included in it a good deal of information derived from official sources and foreign publications. The book is a valuable one. It is usually very accurate, and is well illustrated. Lieut. Very's work is—as far as ships are concerned —less full than the foregoing. Its illustrations are rather rude and many of the figures hardly exact. But in the part devoted to the armaments of naval States is to be found much information which is, probably, not collected in any other single volume." *Prize Essay Notice.*

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS. VOL. IX. No. 1. The use of Austrian steel in shipbuilding. Report of the commission upon the bursting of the 45cm. Armstrong gun on board the Duilio. Description of foreign woods used in the Austrian Dockyards. The relative value of guns. Breech-loaders for the U. S. Navy. Production of steel for guns, in Woolwich. Artillery committees in England. Repeating rifles. Discharging apparatus for fish torpedoes, by H. Chapman. Protection for torpedo boats against mitrailleuses. The Destroyer. New discharging apparatus for fish torpedoes. Compound armor plates in England. Trial trips of the Russian gunboats Doid and Wichr. New vessels for the French Navy. Trial trip of the U. S. Mercury. Building and trial of H. M. Transport Sea-horse. Trial of the Artillery and machinery of the Inflexible. Notes on the English Navy. Smaller iron-clads for the Italian Navy. The relation between the French merchant marine and the French Navy. *Literary Notices. Hydrographic Notices.*

NAUTICAL MAGAZINE. JANUARY, 1881. The weather of the autumn, Sept.—Nov., 1880. Signalling by means of sound. Grain Cargoes. The

new regulations for preventing collisions at sea. Physical examination of pilots and seamen in the United States. *Correspondence. Marine Inventions et cet.*

FEBRUARY, 1881. The stability of the Atalanta. The Atalanta Enquiry. Hydrographical surveys. Minihoi Island. Rotumah Island. Navigation of the Mersey. Decay of American Shipping. *Marine Inventions, et cet.*

MARCH, 1881. Thames pilotage. French merchant shipping bill. Seas between China and Japan. Madras harbor and the proposed canal across the Malay Peninsula. The contagious diseases act. *Correspondence, et cet.*

REVISTA GENERAL DE MARINA. JANUARY, 1881. Notes on electricity (continued). Voyage of the "Marques Del Duero" to Siam and Annam (continued). Relative importance of broadside and fore-and-aft fire, in naval tactics (concluded). Notes on the arrangement of the electric light on board the frigate Sagemto. Naval Tactics on the open sea, with the existing types of vessels and weapons, (Naval prize essay). Translated from the Journal of the Royal United Service Institution). Operations of the Chilian squadron before Callao. Difference between the temperature of the air by the thermometer and by sensation. The Spanish Society for saving the shipwrecked. Notices. *Orders. Movement of Ships.*.

FEBRUARY, 1881. Notes on electricity (continued). Voyage of the "Marques Del Duero" to Siam and Annam (continued). Guide for manœuvres in a hurricane. Economical stores in ships of war. Reform in the colony of Fernando Po. Naval Tactics on the open sea, with the existing types of vessels and weapons. (Naval prize essay. Translated from the Journal of the Royal United Service Institution). Shipwrecks on the coasts of Spain. Marine life saving. Remarks upon the experiments of the Aragon. Notices. *Orders. Movementr of ships.*

MARCH. Notes on electricity (continued). Voyage of the "Marques Del Duero" to Siam and Annam (continued). Game of Naval Warfare (translation). Remarks on the use of torpedo boats, (Translated from the Mittheilungen a. d. Gebiete d. Seewesens). Plating of steel surface for iron clads. Physical geography of the sea. The military arsenal at Shanghai. The Parlador of Lieut. Pinto.' *Notices. Orders. Movements of Ships.*

REVUE MARITIME ET COLONIALE. VOL. 67. 1880. The rolling and pitching of ships. New South Wales. De la Bourdonnais' expedition in the Indian Ocean, in 1746. The merchant marine in England. Determination of the longitude at sea by the method of equal altitudes. English colonies; Leeward, Virgin and Windward Islands. The rôle of artillery in fleet engagements. Statistics of the sea fisheries. China and Japan. The Barometric depressions in Europe, from July, 1877 to Jan. 1880. The naval war between Peru and Chili. *Notes. Bibliography.*

Proposed ship canal from the Atlantic to the Mediterannean. A family in the navy in the 18th century; Beaussier de l'Isle. Helicoidal propellers. Notes on waterspouts. English colonies; Trinidad and English Guiana. Notes on ramming by ships. Directions for avoiding cyclones. The hurricane dromoscope; an instrument for indicating graphically the course to be taken in a cyclone. *Reviews. Bibliography.*

The Pilcomayo; water route from Bolivia to the Atlantic. Note on the Sextant. The Scotch herring fishery, in 1880. Gareis' universal compass, translated from the Meittheilungen a. d. Gebiete d. Seewesens. The sham torpedo fights in England; translated from the Times. The relation between the true velocity of the waves and that observed on board a vessel under way. *Notes. Reviews. Bibliography. Index.*

RIVISTA MARITTIMA. JAN. 1881. The new naval constructions of the Italian Navy, Part II. Military sea-ports; Constantinople, from the *Organ der Militär. Wissenschaftlichen Vereine.* Administative regulations in regard to seamen of the Italian Navy. Naval warfare with the present types of ships and weapons; translation of the discussion in the Royal United Service Institution. The British Merchant Marine. The cellular system of construction for merchant vessels; translation of a paper read before the Institution of Naval Architects. The harbor of Montenegro. Torpedo-boats. The regattas of the *Societa dei Canottieri,* at Palermo. *Notes. Ships in the Italian Navy, Jan.* 1, 1881. Circular of the Italian Geographical Society. Notice in reference to the third International Geographical Congress, to be held at Venice in 1881. Collection of Italian periodicals at the Milan exposition. *Transfers of Officers. Officers of ships in commission.*

FEBRUARY, 1881. Fleet engagements in the future. The enrolment of seamen. The decline of the Italian merchant marine. The changes in the merchant marine, and the re-organization of Italian commerce. Notes on the construction of yachts. Extracts from English consular reports. A letter of Columbus, written to Sanchez, in 1493; with a notice. *Notes. Bibliography. Transfers of Officers. Ships in commission.*

MARCH, 1881. The ancient and the modern ram. Colonies and emigration. Italian consul at the Piraeus. The relation between the true velocity of waves and that observed on board a ship under way, translated from the French. The elements of naval tactics. The micro-telephone of Ader, and experiments on the Turin-Ciriè-Lanzo telegraph. Krants's method and tables for the determination of lunar distances. Bayer's diagram for determining elevations and distances at sea. Italian shipping at Fiume. Extracts from English Consular Reports. John and Sebastian Cabot. Trinity House Rules upon Buoys and Beacons. *Notes. Bibliography. Various Publications. Transfers of officers. Ships in commission.*

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Societé des Ingenieurs Civils, Memoires. Dec., 1880, Jan., 1881.

NAVAL INSTITUTE PRIZE ESSAY, 1882.

A Prize of one hundred dollars and a gold medal of the value of fifty dollars is offered by the Naval Institute for the best essay presented subject to the following rules:—

1. Competition for the prize is open to all members, and to all persons entitled to become members upon payment of dues; that is, to all officers of the Navy and Marine Corps, and to all civil officers attached to the Naval service. But members who have been dropped for non-payment of dues are not eligible for membership until their arrears of dues have been made good.

2. Each competitor to send his essay in a sealed envelope to the Secretary on or before January 1, 1882. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and the writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments, to be selected by the Executive Committee, who will be requested to designate the essay, if any, worthy of the prize.

4. The successful essay to be published in the Proceedings of the Institute, and the essays of other competitors to be published also, at the discretion of the Executive Committee, with the consent of the writers.

5. The subject for the Prize Essay is, " *Our Merchant Marine: the Causes of its Decline, and the Means to be taken for its Revival.*

6. The Essay is limited to forty-eight printed pages of the " Proceedings of the Institute."

7. The money value of the medal may be given to the successful competitor if he so elect, and he will be made a life member of the Institute.

C. BELKNAP.

Lieut. and Secretary.

Annapolis, Md., Apr. 15, 1881.

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. VII. 1881. No. 16.

NAVAL INSTITUTE ANNAPOLIS, MD.,

April 16, 1881.

Commander H. B. Robeson, U. S. N., in the Chair.

SCANDINAVIAN EXPERIMENTS WITH SUBMARINE MINES.

Translated from the original Danish by Lieut. W. H. Beehler, U. S. N.

This paper contains some of the most prominent features of the Scandinavian experiments with submarine mines. I have obtained this information from my translation of the official reports entitled: "*Rapport over Forsœg med Sœminer, foretagne af Sverige, Norge og Danmark i forening 1874–76*" *with* "*Bilag No. 1*"—"*Journal over forsœg med Sœminer*" *and* "*Bilag No. 2*"—"*Beretning om nogle fosog med Sœminer udforte in Carlksrona in October 1873.*

These experiments were conducted by a board of three officers representing Sweden, Norway and Denmark, at Carlskrona, Sweden, though one class of experiments was made at Copenhagen. This board made a thorough scientific investigation into submarine mines, exchanged their results with other European governments, and based their general conclusions upon all the facts known up to the date of their final report, made July 1st, 1877. I believe that these results, with their conclusions therefrom, form the most reliable and thorough treatise on the action, effect, and general application of submarine mines yet published. They divided the subject into four classes; A,, Igniting experiments; B, Experiments with a double bottom ship

equal in all respects to the English iron-clad "Hercules"; C, Experiments with Armor; and D, Countermine Experiments.

Before undertaking these experiments the board made a scientific investigation of the nature of a submerged explosion, and deduced certain laws to express the relation between the depth, charge and distance, and the effects. They divide the effects into two divisions; direct and indirect, and thus determine the effective use of all kinds of submarine mines. They base their investigation upon the known laws governing the explosion of mines in earth, and then, by comparing the two media, deduce theoretical laws which they finally prove by actual experiment. I shall give a concise statement of their methods and the results deduced, and then show how far these results have been demonstrated by their experiments. Unless stated otherwise, the dimensions, weights, &c., are given in English feet and inches, English pounds, &c.

"When a mine explodes in the earth, it raises cohesive masses of earth, compressing some parts and detaching others. If the mine is not too deep it will raise a sundered mass of earth and leave a crater; the earth will tremble beyond the crater for a short time and leave the limits of the direct and indirect effects distinctly marked.

In water, however, the gases evolved press the particles apart instantaneously, and the cavity is filled again almost immediately, so that it is rather difficult to measure the extent of the crater and thus determine the limit of the direct effect. The vibrating area is much greater in water than in earth, and certain definite effects are obtained which are very valuable in the use of countermines."

They assume that it will be impossible to breach a ship unless she is within the limit of the direct effects, and they make their calculations as to the extent of this from explosions of ordinary gunpowder.

"Since an explosion of a charge of gunpowder (submerged so as to be remote from the bottom) forces the surrounding masses of water aside, we will suppose the resistance to be equal in all directions, and then compare the action of the disengaged gases with that of a sphere of gas surrounded by concentric layers of water.

The volume of this sphere, or the cube of its radius, can be regarded as proportional to the charge, so that if L=the charge, R=the radius of the sphere, and M=a coëfficient to be determined, we may express this action by $L = M R^3$. . . . . (1).

This sphere will evidently indicate the limits of the direct effects, and we will designate its radius as the radius of explosion, or R,

which will thus serve as the measure of the force of the explosion. It is evident that the value of R will depend upon the depth and the pressure exerted.

In water the explosion remains concealed below the surface for an instant only; the sphere of gas then begins to ascend with great velocity and carries a mass of water before it, which is thrown out to various heights. If the charge is very deep, the sphere of gas will decrease as it rises, lose its tension, and finally become absorbed so that there will be only a slight ebullition on the surface. In this case the mine is said to be completely smothered. If this same charge is brought nearer the surface, it will soon have a depth at which it will cease to be smothered and, in this investigation, this depth is designated the least depth for smothered mines.

If this charge is brought still nearer the surface, the explosion will cause a funnel-shaped opening or crater in the water. F K M N G (Fig. 1).

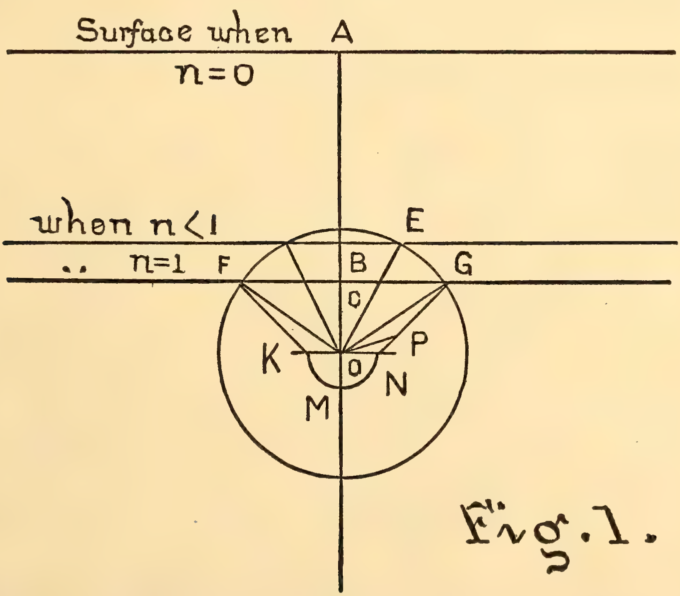

Fig. 1.

This shape is very different from a sphere, and the lengths of the radii of explosion vary in different directions. The mine's direct effect will be greatest in the direction O G, or O E.

In the figure, O A, O B, and O C are the depths, and whenever a crater is produced the depth indicates the line of least resistance.

BE or CG is called the funnel radius or the radius of lateral effect. Let $r =$ equal the funnel radius and $d =$ the depth, and let $n = \frac{r}{d}$, the ratio of the funnel radius and the depth, then $r = d \times n$. If $n < 1$, r will be less than d. In this case we will designate the mine as *undercharged*. If $n = 1$, r will be equal to d, and the mine will be *normal*. If $n > 1$, $r > d$, and the mine will be overcharged.

The greatest mass of water will be thrown out when the mine is *normal*, or when the depth is equal to the funnel radius. When the depth is less than r, the column of water may be thrown to a much greater height, but the mass thrown out will be less than when normal.

Dynamite and gun cotton explode much more suddenly than gunpowder and produce a greater effect when at the overcharged depth; but when at the normal or undercharged depths the phenomena produced by the three explosives differ very little.

We will take the general law for the explosion of mines in earth as applicable to submarine mines and examine the conditions of the two media.

This law is:—Charges which produce similar funnels are proportional to the cubes of their homologous lines.

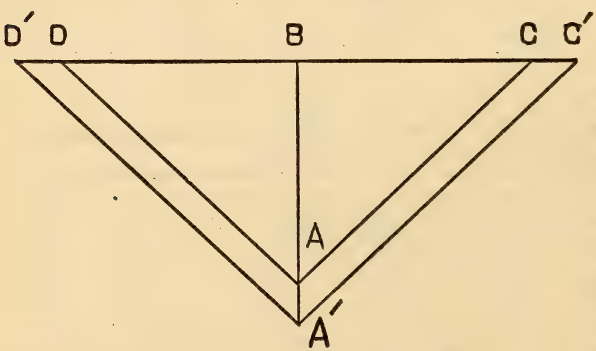

Fig. 2

In Fig. 2.—If we have two charges as A and A′ which produce similar funnels, whose diameters are D C and D′ C′, then A C and A′ C′ will be homologous lines, and $L : L' = (AC)^3 : (A'C')^3$ or $L = \frac{L'}{(A'C')^3} \times (AC)^3$. If we put $AC = R$, and the constant ratio $\frac{L}{(A'C')^3} = M$ we shall have $L = MR^3$, which is identical with equation (1).

But this only applies to mines which produce similar funnels, and

those in which the general conditions for the old law are complied with. This law was deduced from earth mines with slow combustion of gunpowder, and the mode of confinement exerts considerable influence. If two mines of equal charges are confined very differently the force developed will be very different; but if the confinement of each be equal, though applied in a different manner, the force developed will be equal.

The following laws for explosions of earth mines have been firmly established. In earth mines at the normal depth we have

$L_a = \frac{C}{\sqrt{8}} \times R_a$, where L_a = the charge, R_a = the radius of explosion and C = the coëfficient of resistance for the kind of earth.

For mines at the overcharged depth:

$L_o = Cn^3\ (1.05 - .05\ n)^3 \left[\frac{1}{1+n^2}\right]^{\frac{3}{2}} R_o^3$, where L_o, C, and R_o indicate the same as above, and n = the ratio of the funnel radius and the line of least resistance.

For mines at the undercharged depth:

$$L_u = C\left[\frac{4+3n}{7}\right]^3 \times \left[\frac{1}{1+n^2}\right]^{\frac{3}{2}} R_u^3,$$

In mines most overcharged, $n = 3$.

" normal, $n = 1$.

" smothered or most undercharged, $n = 0$.

From these equations we deduce the following when $L_a = L_o = L_u$ and C is constant, $R_a = 1.19\ R_o = 0.91\ R_u \therefore R_o < R_a < R_u$.

Therefore the radius of explosion is greater in a smothered mine and least in a mine at the overcharged depth, and the difference between the normal and overcharged mines, .19, is more than twice that between the normal and undercharged, .09.

By comparing the radii of explosion of normal and undercharged mines which are not smothered, and whose funnel radius is such that $1 > n > \frac{1}{2}$, we find for $n = \frac{1}{2}$, $R_a = .994\ R_u$, which is not very different from that when completely smothered; or $R_a = R_u \times .91$: we may therefore consider the radii of explosion of undercharged mines as practically constant for equal charges.

There is every reason to believe that a similar relation will be true for submarine mine explosions. A normal mine is regarded as a fully confined mine, and these mines develop the same force for equal charges. These may be increased if the mine becomes undercharged; but if overcharged, or at a less depth, the mine will have less confine-

ment, and develop less force and smaller radii of explosion, the decrease being considerably greater than in earth mines.

We conclude from this at once that gunpowder mines can not be used to advantage when the depth is such as to make them overcharged to any extent. Normal, undercharged, and very slightly overcharged gunpowder mines can be used advantageously in water, since their radii of explosion for equal charges are practically constant. We therefore consider the expression $L = MR^3$ also true for submarine mines. In this equation the coëfficient M varies with different explosives; but if the conditions for confinement are complied with, M may be considered constant for the same explosive within certain limits. R depends upon the charge.

The instant the mine bursts its case, the powder gases will be concentrated at the centre, whence they become disengaged on all sides. (In reality the gas is not concentrated at the centre, but as it has its greatest tension there its expansion must be assumed to begin at that point.) We then have the maximum expansion at the centre of the charge, which gradually decreases along the radius of explosion until balanced by the resistance of the surrounding mass of water.

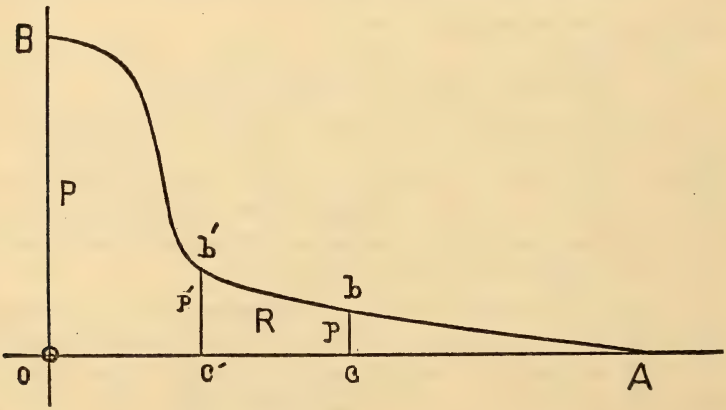

Fig. 3.

If we lay off O A = R, on the abscissas of a right angle system of co-ordinates whose origin O is the centre of the explosion, and lay off the expansion at various points as ordinates, the line joining these points will be the curve of expansion. O B = P is the expansion at

the origin while that at the extremity of the radius of explosion A = zero.

This curve can not be drawn accurately since the law of expansion has not been accurately determined; but it will be sufficient in practice to consider the maximum expansion as determined by the distance at which definite direct effects are obtained, and that the expansion gradually decreases from the centre to the extremity of the radius of explosion.

If we wish to obtain the direct effect on a ship's hull she must be within the distance R from the centre of the mine. If the surrounding resistances are equal in all directions, the destructive effect will be equal in all directions; but this is not the case in practice. We know that the direction of the explosion is perpendicular to the surface of the water because this is the line of least resistance.

It remains to be seen if it is possible to give the line of least resistance such a direction that the greatest effect may be exerted upon the object to be destroyed. In fig. 4, let O be a mine at a depth $ON = d$, SS', the hull of a ship in such a position that $Oc = a$ is less than d; then, if we disregard the resistance of the ship's bottom, the line of least resistance will be in the direction through the bottom of the ship when a is less than the radius of explosion.

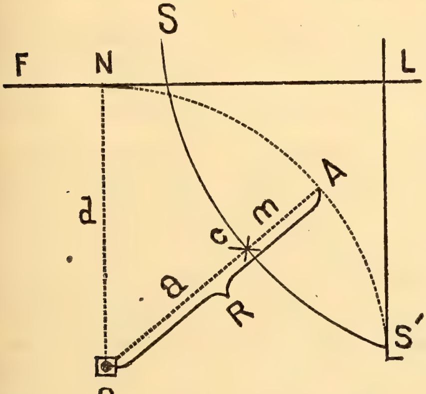

Fig. 4.

But we must take the resistance of the ship's bottom into consideration. In Fig. 3, the intensity of the expansion decreases from P at the origin to zero at A. We may then take the expansion at the point c as equal to p and regard that part of R, A c, as sufficient to breach the ship, and then this may be reckoned as the resistance of the ship, or m. Therefore a mine must be at a distance $= R - m = a$ from a ship in order to effect a breach. This distance a is called the *breaching radius.*

Since R is a measure of the explosive force, the explosion may be regarded as sufficient to penetrate a mass of water of R thickness;

and in the same way m may be regarded as equivalent to a mass of water of m thickness, the resistance of which is equal to the resistance of the ship. Therefore we can express this condition thus:—that the distance from the mine to the ship's bottom must be such that $a \leqq R—m$, and that the mine's depth d must be greater than R.

Since it will often be desirable to attack very light draught vessels it will be difficult to make $d > R$, because the depth must not be so great as to bring the ship beyond the distance R—m from the mine when directly over it. If we let the ship's draught be g then $d—g$ should $= R—m$, and as light draught vessels may be very strongly built g may be taken as equal to m; whence $d=R$ and not greater than R. In this case we should have very little lateral effect, and where that is necessary the maximum will be obtained at the normal depth, or when $d = .71R$, and the value of the *breaching radius* becomes $a \leqq .71R—m$.

The above only applies to gunpowder mines; with dynamite or guncotton it will be sufficient if the mine has its requisite confinement and if $a \leqq R—m$; but, in order to obtain the greatest possible lateral effect, it will be necessary to have the normal or even overcharged depth. We cannot expect a complete breach unless the above conditions are complied with, though a ship may often be seriously damaged by the shock of the projected mass of water.

We have heretofore only considered buoyant mines, but when a mine rests on the bottom the explosion will be influenced by the bottom. When a mine rests on the bottom the volume of gas cannot assume the shape of a sphere; if the bottom be very hard, it will be very nearly a hemisphere, the volume of which will be such that $R' = R\sqrt[3]{2} = 1.26R$. This has been demonstrated by the experiments with gunpowder; but whenever these mines produce a *crater*, the greater effects appear in the line of least resistance only, and the lateral effect is not increased.

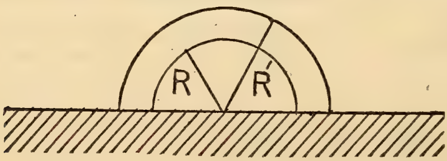

Fig. 5.

If a charge rests on the bottom, at the normal depth, the *crater* is

not larger than if buoyant; but it will, figuratively speaking, give a cleaner funnel. The destructive effect is especially enhanced if a ground mine is at the undercharged depth; and experience shows that the radii of explosion increase to $R' = 1.26R$. With dynamite or gun-cotton the proximity to the bottom will not make so much difference, although a slight increase in the radii of explosion may be expected.

Determination of the Coefficient M.

In the equation $L = MR^3$, M must be determined by experiment for every kind of explosive. From these experiments we find that 4 lbs. of gunpowder at a depth of 4'.1 gives a funnel radius a little over 4' and 400 lbs., 19' deep, gives a funnel radius about 19'.

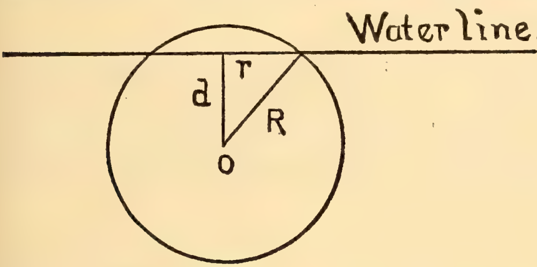

Fig. 6.

Let $r =$ the funnel radius,
$d =$ the depth,
$R =$ the radius of explosion,
$L =$ the charge and $M =$ the coëfficient.

We have from the figure $R^2 = d^2 + r^2$ or $R = \sqrt{d^2 + r^2}$ then for 4 lbs. at 4.'1 deep, $R = \sqrt{4.1^2 + 4.1^2} = 5.79'$ and 400 lbs. at 19'. deep give $r = 19$, $R = \sqrt{19^2 + 19^2} = 26.9'$.

Putting these values of R in the equation $L = M R^3 \therefore M = \frac{L}{R^3}$, we have for 4 lbs., $M = \frac{4}{5.79^3} = \frac{1}{48.5}$; for 400 lbs., we have $\frac{400}{26.9^3} = \frac{1}{48.6}$. In practice, then, we can say that $M = \frac{1}{48.6}$, and then substituting in (1) we have $L = \frac{R^3}{48.6}$; or when L is known, $R^3 = L \times 48.6$, or $R = \sqrt[3]{48.6 \times L}$: reducing we get

$$R = 3.65\sqrt[3]{L} \quad \ldots\ldots\ldots\ldots \quad (2).$$

This value of M is true for mines, at the normal, undercharged, and slightly overcharged depths.

In calculating the charge for mines in earth it is customary to use d in the previous equations, or the line of least resistance instead of

R. In this case, equation (1) becomes $L = \frac{d^3\sqrt{8}}{48.6} = \frac{d^3}{17}$ (3).

By comparing this with so called *average* earth it is well known that for the normal funnel $L = \frac{d^3}{10}$

Average earth has a specific gravity of 1.82 } Laisné, *Aide*
Sea-water " " " 1.03 } *Mémoire.*

The ratio of average earth and sea-water $= \frac{1.82}{1.03} = \frac{1}{1.77}$

Substituting this in $L = \frac{d^3}{10}$, we have $L = \frac{d^3}{17.7}$ which agrees very nearly with (3).

In Laisné, *Aide mémoire de l'Officier du Genie*, we find a convenient rule for ascertaining when a mine will throw out a column of water; this is put as $L = d^3$. Here L is in kilogrammes and d in metres and when reduced to English feet and pounds we have

$2.2 \times L = (3.28d)^3 \therefore L = \frac{d^3}{16}$

Another French formula makes $L = \frac{d^3}{17.9}$ and, finally, the Prussians use the formula $L = \frac{d^3}{15}$; so that from all these values we consider $L = \frac{d^3}{17}$ to be accurate for all practical purposes."

Determination of M for Dynamite or Gun Cotton.

The results of a great many experiments made in Denmark, England, Italy, and other countries were considered and from them the relative force of gunpowder to dynamite and gun cotton is found to be as 1 : 3 or 4; provided the mines are sufficiently confined. It is also seen that dry gun cotton is a little weaker and less sudden than dynamite. Wet gun cotton explodes more suddenly and with greater force than dry gun cotton.

"From equation (2) we have $R = 3.65 \sqrt[3]{L}$ for gunpowder, or that the radius of explosion of 1 lb. of gunpowder is equal to 3.65. Comparing this with the relative force of gunpowder to dynamite we have for 1 lb. of dynamite; $1 : 3 = 3.65 : 3.65\sqrt[3]{3} = 5.26$

$$1 : 4 = 3.65 : 3.65\sqrt[3]{4} = 5.8$$

Therefore the radius of explosion of 1 lb. of dynamite is between 5.26 and 5.8 and we have adopted

$R = 5.5\sqrt[3]{L}$ for dynamite, and

$R = 5.35\sqrt[3]{L}$ " dry compressed gun cotton."

These values were deduced from experiments with small charges of dynamite and guncotton, and they will be further considered in the course of the experiments with larger charges.

The Least Depth of Smothered Mines.

"This is the greatest depth at which mines will be effective against large draught vessels. It will be necessary to consider this when desiring to blow up a sunken wreck, and especially when we want to have certain indirect effects which are greater from smothered mines than from mines which produce a *crater*. If the explosions were perfectly instantaneous this depth D would be equal to the radius of explosion; but it is only in practice that dynamite and gun cotton mines can be considered to explode thus instantaneously.

Explosions in earth show that the least depth for a mine not to produce a *crater* $= 1.75 \times d$, where d is the normal depth of the same charge. When R equals 1 in earth mines, we have

$$d : R : D = 0.71 : 1 : 1.24.$$

This is similarly the case in water, and some experiments made at Copenhagen in 1870 confirm this. In these

3.3	lbs. of	gunpowder	were	completely	smothered	when	10′—12.3′	deep
6.6	"	"	"	"	"	"	11.3′	"
8.8	"	"	"	"	"	"	14.4′	"
13.2	"	"	"	"	"	"	14.4′	"

the last charge being just at the limit. These results were too few and indecisive. (1)

If we take 13′.39 as a depth at which 13.2 lbs. of gunpowder will be smothered, the depths for the other charge may be deduced from the general law; so that 3.3 lbs should be 8.23′ deep; 6.6 lbs., 10.6′; 8.8 lbs. 11.63′. This would make the ratio between d, R, and D, when $R = 1$, as $d : R : D = .71 : 1 : 1.55$, or the least depth for smothered mines is a little more than twice the normal depth of the same charge. This depth is greater in ground mines than in buoyant, probably less than 2R, but if the bottom is very hard it may be equal to 2R."

The Indirect Effects of Mines.

In considering this subject the report quotes from Moisson's *Etude sur la Question des Explosions Sousmarines.* "'From this the gases developed by a submarine explosion are found to impart a succession of shocks to a series of concentric layers of water, with a velocity of 1400 metres per second. When the shock is being transmitted, each of the successive layers is alternately compressed and rarefied, so that waves of compression and rarefaction follow each other with the velocity of the transmission, until the explosion is exhausted. Any foreign body in the water will receive a shock from the nearest compressed molecules of water. The outside molecules of the body will be compressed and transmit the wave of compression to the next layer of molecules; other impulses then quickly follow, and finally destroy the body. If the molecular action is quicker in the body than in water, the body will be merely compressed at the part attacked; if not, the impulse will be carried through the body: in neither case, however, will the body be moved.'

This explains the phenomena due to the indirect effects of an explosion, but the law for the indirect effects will have to be determined by experiment. We find the following phenomena due to the indirect effects; viz., fish are killed and stunned over a large area; electric circuit closing apparatuses are caused to make contact, mine cases are damaged and destroyed and their charges of dynamite often exploded even at relatively great distances from the centre of explosion. Ropes and electric cables are uninjured by the indirect effects, and observation proves that objects are not displaced by them. Dynamite mines explode more suddenly than gun-cotton mines and give the greatest indirect effects. Gunpowder gives the least indirect effects; but in all cases these are the greatest when the mines are smothered.

The indirect effects are very important as influencing the construction and material of mine cases and circuit closing apparatus, the disposition of dynamite in the cases, the determination of the mutual distance of mines in a system, and the use of countermines in clearing a channel. And, since fish are killed or stunned by the shock of the indirect effects, it follows that divers cannot operate when exposed to them.

The laws for the indirect effects have not been determined and they will be considered in the course of these experiments."

The Board commenced their experiments in August, 1874, made their final experiment in September, 1876, and sent in their report on

July 1st, 1877. As this board exchanged information with most of the European governments, the latest inventions up to July 1877 were duly considered by them in their report.

REPORT OF THE EXPERIMENTS.

In class A, the Board conducted a series of experiments to ascertain the best method of igniting gunpowder mines and to determine the radius of explosion of dynamite. Fifteen experiments with 112 lbs and five with 654.5 lbs of gunpowder were made. In these the mines were surrounded by empty tinned steel cylinders $\frac{1}{32}''$ thick, $10''$ in diameter, and $12''$ high, called *pressure cases;* and the alteration in the shape of each case was taken as an indication of the force of the explosion at its distance from the mine. These would thus measure the indirect effects, and all the igniting experiments were made with due reference to ascertaining the laws governing them.

Seven introductory experiments were made at Carlskrona with charges of gunpowder in iron cylindrical cases with convex ends; the first two were $\frac{1}{8}''$ thick, the last $\frac{1}{2}''$, and the others $\frac{1}{4}''$ thick. These had an internal capacity of 1.4 cu. ft. and were charged with gunpowder in each case.

No. 1 of 116 lbs., and No. 3 of 227 lbs were ignited by an electric igniter in a bag of gunpowder at the centre. No. 2 of 122 lbs., No. 4 of 228 lbs., and No. 5 of 231 lbs., were ignited by an electric igniter with a charge of 23 grains of fulminate at the same place. No. 6 of 247 lbs., was ignited by an electric igniter with 324 grains of dynamite and 23 gr. of fulminate. No. 7 of 444 lbs., was ignited by one electric igniter with a small charge of fulminate.

From these experiments it was found that if a powerful detonating igniter for gunpowder in very thin cases is used, the cases will be apt to burst before the entire charge is ignited; but that in cases $\frac{1}{4}''$ thick a detonating ignition may be advantageous; and that cases thicker than $\frac{1}{4}''$ will not be necessary. Three or four pressure cases were used in each of these seven introductory experiments, but as they were placed in a single line their results are not compared with others.

In each of the fifteen experiments with 112 lbs. of gunpowder, six pressure cases were placed at a depth of 9.7 feet in three lines, making an angle of 120° with each other and 20 and 30 feet from each mine. The powder used was Swedish musket, made in 1866.

CLASS A.

IGNITING EXPERIMENTS WITH 112.2 LBS. OF GUNPOWDER, 9.7′ DEEP. CARLSKRONA, 1874.

Date.	Number.	Case.	Method of Ignition.	Effects upon the Pressure Cases. At 19.2′ from the Mine. X	XX	XXX	At 29.2′ from the Mine. X	XX	XXX	Characteristic Number.	Remarks.
1874. Aug. 26.	Sec. "a". 1	Steel Plate 1-16″ thick.	By 2 fuzes in the axis of the Mine.	The pressure cases at this distance were all compressed from an original height of 11.6″ to from 7.2″ to 5.9″, in all three experiments. The sides were badly deformed. The ends were deformed and partly severed.			At this distance the pressure cases were compressed from 11.6″ to 10.6″ and 10.2″. Sides deformed. Ends deformed and partially severed.			85	The marks X, XX and XXX, indicate the three directions, 120° apart, in which the pressure cases were placed. The characteristic number is simply a relative number, arbitrarily using 100 as the maximum.
Aug. 27.	2	"	By 2 fuzes along the side.								
Aug. 27.	3	"	By 10 fuzes, 2 in the axis, 8 in a spiral on the side.								
Sept. 2.	4	"	By means of a glass tube filled with powder and ignited by two of Ebner's Igniters.	The cases were compressed to 4.5″ and 5.1″. Sides completely deformed. Ends deformed and partially severed.			Compressed to from 10.6″ to 10.2″. Sides deformed. Ends deformed and partially severed.			100	
Sept. 3.	5	Iron Plate 1-16″ thick.	Stewart's branch tube consisting of a leaden tube covered with wire gauze, containing small igniting charges of gunpowder and two igniters.	Case compressed to a mass.	Original height retained. Sides and ends slightly deformed.	Compressed to 4″. Sides completely deformed. Ends deformed and bent in.	Original heights retained. Sides and ends slightly deformed.				No characteristic can be given for this experiment because the effects were chiefly in the direction of X.

CLASS A—c—

TABLE OF THE EXPERIMENTS FOR IGNITING 654.5 LBS. OF MUSKET POWDER.—CARLSKRONA 1875.

Date.	Number.	Method of Ignition.	Kind of case used.	Depth of the water and of the mine.	Description of the Pressure Cases and Pressure Gauges. Number and Kind.	Distance from the mine.	Depths.	Relative positions of the P. Cases and P. Gauges.	Effects on Pressure Cases. Original height. How Deformed.	11.69" Compressed to Each.	Mean	Effects upon the Pressure Gauges. Swedish Pressure Gauges in atmospheres. Each,	Mean	French Pres. Gauges in millimetres. Each.	Mean	Characteristic Number.	Remarks.
Aug. 7th	1	By 2 of Ebner's fuzes with an igniting charge of 385 gr'ns of powder in a tin tube.	An iron cylinder ¼" thick.	29.2' deep in 34' of water	3 Swedish P. Gauges.	28.2'	8.7'	X XX XXX				13 15.5 (22)	14.25				X, XX, XXX, indicate the directions in which the pressure cases and gauges run from the mine's centre; each direction was 120° from the others.
					4 Pressure Cases.	33'	15.6'	XX XXX	Sides and ends badly.	4.33" 4.73"	4.53"	12 14.75	13.4				
					4 Swed'h P. Gauges	39'	30.16'	XX XXX	Completely.	3.54" 3.54"	3.54"	13 19	16			100	
					4 Press. cases.	58.3'	15.6'	XX XXX	Sides and ends partially.	6.5" 6.9"	6.7"						
					2 Swedish P. cases.	58.3'	30.16'	XX XXX	Sides very badly, one end car away	4.9" 5.3"	5.6"	12.5 (17.2)					
Aug. 10th	2	By 2 of Ebner's fuzes with 25 grains of fulminate.	"	27.4' in 34' of water	3 Pressure cases.	48.5'	29.2'	X	Ends & sides badly	4.73"	4.59"	15					Mc Evoy's Circuit closer apparatus in an iron case with a wooden cover was placed at a depth of 9.7' and 146' from the mine. It was connected to a battery of 10 cells and a galvanometer. This explosion deflected this needle 60 degrees.
					3 Swedish P. Gauges.	"	"	XX	One end severed irregularly & badly.	3.7"		(24)	15				
								XXX	Completely.	3.74"		15				100	
					3 Pressure cases.	68'	"	X	Sides badly, ends loosened.	6.89"		7 7	7				
					3 Swedish P. Gauges	"	"	XX	Very badly, one end lost.	6.1"	6.16"	7					
								XXX	Very badly.	5.51"							
Aug. 12th,	3	By 2 of Ebner's fuzes with an igniting charge of .28 lbs. of powder in a glass tube.	"	"	3 Swedish P. Gauges.	29.2"	29.2'	X XX XXX				(13.5) 32.5 31.5	32				A Swedish circuit closer apparatus was placed at a depth of 9.7' and 146' from this mine. It was connected to a battery of 10 cells and a galvanometer, but the needle was not affected by the explosion.
					3 Pressure cases.	48.5"	29.2'	X	Sides & ends badly & irregularly. Ends loose.	4.9"		14.5		1.75			
					3 Swedish Gauges.	"	"	XX	Very badly ends loose.	5.3"	4.97"	14.5	13.9	1.75	1.83	100	
					3 French Gauges.	"	"	XXX	Almost completely.	4.73"		12.75		2			
					3 Pressure cases.	68'	"	X	Very badly. one end loosened	6.1"		6.5		0			
					3 Swedish P. Gauges.	"	"	XX	Sides & ends badly one end loosened.	6.3"	5.48"	5	62	1	1.67		
					3 French P. Gauges.	"	"	XXX	Very badly and irregularly.	3.94"		7		4			
Aug. 13th,	4	Same as that used in No. 1.	"	"	3 Swedish P. Gauges.	29.2'	29.2'	X XX XXX				29 23.25 36	32				The effects of the explosions are much smaller, owing to the powder used in the charge which was made in 1853: the powder generally used was made in 1866.
					3 Pressure cases.	48.5'	"	X	Very much.	4.53"		15.5		1.5			
					3 Swedish P. Gauges.	"	"	XX	Ends loosened.	5.1"	5.97"	15.25	15.1	0	.5	80	
					3 French P. Gauges.	".	"	XXX	Badly, one end lo'se	8.27"		14.5		0			
					3 Pressure cases.	68'	"	X	Badly, one end lo'se	8.27"		7		1.5			
					3 Swedish P. Gauges.	"	"	XX	Sides defrm'd ends loose.	9.25"	8.46"	7.5	7.25	0	.5		
					3 French P. Gauges.	"	"	XXX	Sides badly deformed, one end loose.	7.87 '		(13)		0			
Dec. 2.	5	By 12 fuzes in a spiral along the surface one at eve'y 3" of the charge.	"	29.2' in 39' of water	Pressure cases.	48.5	29.2'	X	Sides badly, one end loose.	6.5"				1.4, 1.2, 1.1	1.23		The fuzes used had an electrical resistance of from 29,000 to 36,000 ohms. Siemens. They were ignited by Siemens' D. E. machine.
					3 Trebled French P. Gauges.	"	"	XX	Sides and ends completely.	4.33"	4.99"			1.7, 2.2, 3.5	2.47	2.16	
			"					XXX	Sides & ends & one end loose	4.13"				3. 2.9, 2.4	2.77	100	
					3 Pressure cases.	68'	"	X	Sides completely 1 end carried away.					0.2 0.2			
					5 single F. P. Gauges	"	"	XX XXX	" " " "					0.9 0.9 1.4	83		

		bottom.		and ends badly deformed.	and ends deformed.	def'm'd. Ends deformed.	slightly deformed.	slightly d'form'd. Ends d'form'd.	slightly deformed in parts.		
Oct. 8.	10	Iron Plate ¼'' thick. Charge chamber at the bottom.	Musket Powder ignited by 23 grains of fulminate of mercury.	19.5' from the mine. Compressed to 7.8'' & 8.4'' Sides and ends badly deformed. A pressure gauge was placed under each of these three cases and indicated the following.			29.2' from the mine. Compressed to 11.1'' and 11.3'' Sides and ends slightly deformed.			70	In this the effects were very equally distributed.
				X A little more than 10 Atmos.	X X A little more than 10 Atmos.	X X X 10 Atmos.					

In the next ten experiments the same size of charge and similar methods of ignition were used, and at the same time a comparison was made of the influence of the strength of cases for buoyant mines, and it was sought to ascertain the best position for the charge in its buoyant case. The charge chambers were cylinders of $\frac{1}{32}''$ steel plate of two different shapes, one being low and broad and the other high and narrow; the former kept the charge at the bottom and the latter evenly distributed along the axis of the case. Each mine was ignited by four fuzes, one at the center and three at different heights along the outer surface. See table Class A—b—

From these it is found that a charge of 112 lbs of gunpowder develops its greatest force when it entirely fills a case of steel plate $\frac{1}{16}''$ thick; also that air spaces in a mine weaken the effect. The effect decreases very much with the thickness of the case, and this, for 112 lbs. of gunpowder, must not exceed $\frac{1}{4}''$. Cannon powder was tried in the 7th and 8th experiments with about the same effect. From the results of the explosions the Board concludes that the mine cases must not be too tough, and that the joints should be as strong as the other parts of the case.

It does not make any essential difference which of the two methods is used for the position of the charge in a buoyant case.

From these results, the Board recommends a fuze composed of 1960 grains of gunpowder with two electric igniters in a glass tube at the centre of the charge, as a safe, convenient, and effective means for igniting all gunpowder mines up to 654.5 lbs. See third experiment in table Class A—c—

In class A the Board made some experiments to ascertain the radius of explosion of dynamite. They exploded fifty charges of dynamite varying in size from 4.66 lbs up to 37.4 lbs, the first series being made in 1873 with the introductory experiments. They intended to make this determination by using iron or zinc targets; but, as this method was tried in other countries and gave unsatisfactory results, they used a float of four pieces of timber enclosing a rectangular surface of water of 26.3 feet square. The charges of dynamite were suspended at different depths below the centre of the enclosed space by means of a davit on one of the floats. In the first nineteen experiments ropes were passed from the sides of the float to converge at a point over the mine; and the distance of the broken parts was taken as the extent of the direct effect in each experiment.

CLASS A.—b—

IGNITING EXPERIMENTS WITH 112.2 LBS. OF GUNPOWDER, 9.7′ DEEP, CARLSKRONA, 1874.

Date.	Number.	Description of Case.	Method of Ignition.	Effects upon the Pressure Cases. 19.5′ from the Mine. X	XX	XXX	29.2′ from the Mine. X	XX	XXX	Charateristic Number.	Remarks.
1874. Aug. 28.	Sec. "b" 1	Iron Plate ⅜″ thick, with a charge chamber inside, long and narrow, fitting between ends.	Musket Powder, ignited by four fuzes. One at the centre, three at the surface.	All three compressed to from 7.8″ to 7″. Sides badly deformed. Ends deformed and partially severed.			All three compressed to from 10.6″ to 10.2″ Sides and ends deformed. Ends partially severed.			80	
Aug. 28.	2	Iron Plate ⅜″ thick, Charge chamber at the bottom, being broad and low.	As above.	All three compressed to from 10.2″ to 9″. Sides badly deformed. Ends almost completely severed.			All three compressed from 10.9″ to 10.2″. Sides somewhat deformed. Ends deformed and partially severed.			65	Divers picked up pieces of the mine case from which it was evident that the ⅜″ cases were burst, while the ¼″ and ⅜″ cases were severed at the line of rivets; pieces of these last mines were almost entire and some of the cylindrical shells were merely bulged out and not burst except at the rivets.
Aug. 28.	3	Iron Plate ¼″ thick. Charge chamber in the axis, as in the first experiment.	As above.	Two cases compressed to 10.2″. One case compressed to 7.8″. Sides badly deformed. Ends deformed and partially severed.			Not compressed. Sides uninjured; the bottom slightly indented.			40	
Aug. 28.	4	Iron Plate ¼″ thick. Charge chamber at the bottom as in No. 2.	As above.	Comp. to 9.8″	Comp. to 8.6″	Comp. to 5.9″	Compressed to 10.9″ and 11.2″. Sides slightly deformed. Bottom deformed and severed.		Comp. to 10.6″ Deformed.	65	Swedish iron was used for all the cases.
				Sides badly deformed. Ends deformed and severed.							
Aug. 29.	5	Iron Plate ⅜″ thick. Charge chamber in the axis as in Nos. 1 and 3.	As above.	All three compressed to 10.6″ and 10.2″ Sides deformed. Ends deformed and severed.			All compressed to 10.9″ and 11.4″. Sides scarcely injured. One bottom slightly indented.			35	
Aug. 29.	6	Iron Plate ⅜″ thick. Charge chamber at the bottom as in Nos. 2 and 4.	As above.	All compressed to 10.6″ and 10.9″ Sides partly deformed. Ends " "			Uninjured.			30	
Sept. 1.	7	Iron Plate ⅜″ thick. Charge chamber at the bottom.	Cannon Powder ignited as above.	All compressed to 6.2″ and 7.4″ Sides badly deformed. Ends deformed and severed.			Compressed to 10,9″ and 10.2″ Sides slightly deformed. Ends deformed and severed.			80	
Sept. 1.	8	Iron Plate ¼″ thick. Charge chamber at the bottom.	Cannon Powder ignited as above.	All compressed to 8.2″ and 9.4″ Sides and ends badly deformed. Ends entirely severed in parts.			Compressed to 10.9″ Sides slightly deformed. Ends deformed and partially severed.			65	
Sept. 29.	9	Iron Plate ¼″ thick. Charge chamber at the bottom.	Musket Powder ignited as above.	16.6′ distant. Comp. to 7.8″ Sides and ends badly deformed.	24.3′ distant. Comp. to 7.2″ Sides and ends deformed.	19.5′ distant. Comp. to 10.8″ Sides partly def'm'd. Ends deformed.	26.3′ distant. Comp. to 10.9″ Sides and ends slightly deformed.	33.1′ distant. Comp. to 11″ Sides in places slightly d'form'd. Ends d'form'd.	29.2′ distant, Comp. to 11.1″ Sides and ends slightly deformed in parts.	70	In the ninth experiment the effects were unequal in the different directions.
Oct. 8.	10	Iron Plate ¼″ thick. Charge chamber at the bottom.	Musket Powder ignited by 23 grains of fulminate of mercury.	19.5′ from the mine. Compressed to 7.8″ & 8.4″ Sides and ends badly deformed. A pressure gauge was placed under each of these three cases and indicated the following.			29.2′ from the mine. Compressed to 11.1″ and 11.3″ Sides and ends slightly deformed.			70	In this the effects were very equally distributed.
				X A little more than 10 Atmos.	XX A little more than 10 Atmos.	XXX 10 Atmos.					

In the next ten experiments the same size of charge and similar methods of ignition were used, and at the same time a comparison was made of the influence of the strength of cases for buoyant mines, and it was sought to ascertain the best position for the charge in its buoyant case. The charge chambers were cylinders of $\frac{1}{32}''$ steel plate of two different shapes, one being low and broad and the other high and narrow; the former kept the charge at the bottom and the latter evenly distributed along the axis of the case. Each mine was ignited by four fuzes, one at the center and three at different heights along the outer surface. See table Class A—b—

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Seven charges of 5.7 lbs. of dynamite were exploded at depths of from 4.7′ to 11.7′.

Seven charges of 11.2 lbs. of dynamite were exploded at depths of from 8.75′ to 16.5′.

Five charges of 22.4 lbs. of dynamite were exploded at depths of from 10.7′ to 22.4′.

These explosions indicated that the direct effects of

5.7 lbs.	of dynamite	extended to	a distance of	12.7′	from the	mine.
11.2	"	"	"	16.4′	"	"
22.4	"	"	"	20.9		"

The cubes of these distances are as the charges, and this proves the general law previously deduced; but these distances cannot be taken as accurate lengths of the radii of explosion, because the coëfficient in the general equation $R = M \sqrt[3]{L}$ would then be 7.4, which, when compared with the coëfficient of gunpowder, would make the relative force of gunpowder be to that of dynamite as 1 : 8.2 which is contrary to experience. This is probably due to the fact that the mass of water thrown out acted as a projectile on the ropes and broke them beyond the periphery of the mine's funnel. The relative distances in these experiments, however, confirm the general law in so far as to establish that the charges vary as the cubes of these distances.

In the remaining experiments the ropes were passed parallel from the opposite sides at regular intervals of one Danish foot = 0.97 English foot. Those which were broken indicated the extent of the funnel radius at the surface. The mines were suspended at different depths below the centre as before. From these we find the following values for the radii of explosion.

4.67 lbs.	dynamite	from 4.85′	to 7.8′	deep give	R =	from 7.8′	to 8.8′
9.35	"	"	7.8′	" 9.7′.	"	=	" 9.7′	" 10.7′
18.7	"	"		" 11.7′	"	=	" 12.7′	" 13.6′
37.4	"	"	11.7′	" 14.5′	"	=	" 15.7′	" 16.6′

or taking a mean, we have 8.3′, 10.5′, 13.1′, and 16.5′ as the radii of explosion for these charges respectively. These values of R vary as their cubes to the charges, and when substituted in the general equation make the coëfficient for dynamite equal to 5.5 which agrees with the previous calculation. The Board therefore concludes that the equation $R = 5.5 \sqrt[3]{L}$ is true for dynamite.

If the charge L is expressed in kilogrammes and R in metres, the equation becomes $R = 2.17 \sqrt[3]{L}$ kilogrammes.

Seven charges of 5.7 lbs. of dynamite were exploded at depths of from 4.7′ to 11.7′.

Seven charges of 11.2 lbs. of dynamite were exploded at depths of from 8.75′ to 16.5′.

Five charges of 22.4 lbs. of dynamite were exploded at depths of from 10.7′ to 22.4′.

These explosions indicated that the direct effects of

5.7	lbs. of	dynamite	extended to a distance of	12.7′	from the	mine.
11.2	"	"	"	16.4′	"	"
22.4	"	"	"	20.9		"

The cubes of these distances are as the charges, and this proves the general law previously deduced; but these distances cannot be taken as accurate lengths of the radii of explosion, because the coëfficient in the general equation $R = M \sqrt[3]{L}$ would then be 7.4, which, when compared with the coëfficient of gunpowder, would make the relative force of gunpowder be to that of dynamite as 1 : 8.2 which is contrary to experience. This is probably due to the fact that the mass of water thrown out acted as a projectile on the ropes and broke them beyond the periphery of the mine's funnel. The relative distances in these experiments, however, confirm the general law in so far as to establish that the charges vary as the cubes of these distances.

In the remaining experiments the ropes were passed parallel from the opposite sides at regular intervals of one Danish foot = 0.97 English foot. Those which were broken indicated the extent of the funnel radius at the surface. The mines were suspended at different depths below the centre as before. From these we find the following values for the radii of explosion.

4.67	lbs. dynamite	from 4.85′	to 7.8′	deep give R	=	from 7.8′	to 8.8′
9.35	"	" 7.8′	" 9.7′.	"	=	" 9.7′	" 10.7′
18.7	"	"	" 11.7′	"	=	" 12.7′	" 13.6′
37.4	"	" 11.7′	" 14.5′	"	=	" 15.7′	" 16.6′

or taking a mean, we have 8.3′, 10.5′, 13.1′, and 16.5′ as the radii of explosion for these charges respectively. These values of R vary as their cubes to the charges, and when substituted in the general equation make the coëfficient for dynamite equal to 5.5 which agrees with the previous calculation. The Board therefore concludes that the equation $R = 5.5 \sqrt[3]{L}$ is true for dynamite.

If the charge L is expressed in kilogrammes and R in metres, the equation becomes $R = 2.17 \sqrt[3]{L}$ kilogrammes.

CLASS B.

Table of the Experiments made with the ship Foersigtigheten, built like the iron-clad Hercules.

Date.	Number.	Weight of the charge, kind of Case, and Method of Ignition.	Position of the Mine. Depths.	Distance from the Target. Horizontally.	Distance from the Target. Actual.	Distance from the edge of the Target. From the Keel.	Distance from the edge of the Target. Target's lower edge.	Distance from the edge of the Target. Target's nearest side edge.	Draught amidships.	List to Port.	Part of the Target which was nearest the Mine.	Effects of the Explosion upon the Ship and the Target.
1874. Sept. 19.	1	32.7 lbs of Dynamite. Case of tinned steel 1-32" thick. Ignited by 1 Electric Igniter and 23 grains of fulminate.	9.3'	24.3'	25.4'				14.3'	28.3" * See Note.	Opposite the 7th Frame.	The ship received a violent shock, some of her wooden connections were broken, three rivets were loosened in the fore-and-aft bulkhead amidships, but no leak could be found by divers.
Sept. 21.	2	46.75 lbs. of Dynamite. Case and Ignition as No. 1.	9.3'	24.3'	25.4'				14.2'	25.2"	Opposite the 3rd Frame.	The ship was affected as in the first experiment. Five rivets were stripped and driven in ⅛". No leak of any importance could be found, but the ship made 3' or 4' of water in the space behind the target during the course of the night.
Sept. 23.	3	112.2 lbs. of Powder. In a tinned steel charge chamber 1-32" thick, enclosed in an iron case ⅛" thick. Ignited by 4 Electrical fuzes.	9.3'	9.75'	12' from the centre of case, and 12.2' from the centre of charge.	32.7'	26.3'	19.5'	14'	10.6"	Opposite the 5th Frame, or the centre of the target.	A large leak was found in the target above the 5th frame. The water rose quickly in the lowest compartment in the target. The ship was docked immediately. The target was indented on both sides of the centre frame, 7.8" above the water line to 8' or 9' below. The deepest indentation was 1½" deep at about 3' below the water line. The 5th frame was not buckled. 239 rivets in the outer bottom plates were stripped and broken. A great many rivets and bolts were also damaged inboards in the inner planking and the athwart ship bulkhead.
Oct. 9.	4	As in No. 1.	9.3'	14.9'	16.7'	32.7'	31'	18.3'	13.8'	24.4'	Opposite the 7th frame.	The explosion threw out a very small column of water. No leak could be found. Two rivets were broken and two were loosened in the wake of the 8th frame.
Oct. 9.	5	65.4 lbs. of Dynamite. Case and Ignition as No. 1.	9.3'	19.5'	21.1'	32.7'	35.6'	22.4'	13.8'	20.5"	Opposite the 3rd frame.	The explosion threw out a large column of water. No leak could be found. Two rivets were broken and two were loosened in the wake of the 2nd frame.
Oct. 10.	6	Charge, Case and Ignition same as in No. 1. 32.7 lbs. of Dynamite.	9.3'	10.5'	12.8'	33.1'	26.7'	14.9'	14'	18.5"	Opposite the 7th frame.	Ship trembled. Four rivets were broken and four loosened in the wake of the 7th frame. Three were broken, two loosened in the wake of the 6th frame, and some rivets were stripped and loosened between the 8th and 9th frames. A small leak was found between the 7th and 8th frames. The outer bottom was indented between the 6th and 7th, the 7th and 8th and the 8th and 9th frames. It commenced about a few inches above the water line and extended to 9.8' below. These indentations were 1¼" deep forward of the 8th frame and ⅝" abaft this frame.
Oct. 19.	7	32.7 lbs. of Dynamite. In a case like No. 1, and ignited in the same manner.	9.3'	4.3"	4.1'	23.4'	16.8'	12.3'	14.1'	11.7"	Opposite the 4th frame.	Ship listed to starboard. Half of the space behind the target was immediately filled with water. The other half was soon filled by a leak in the centre bulkhead. The ship was docked at once. Both bottoms were breached between the 2nd and 3rd string-pieces and the 2nd and 5th frames with a hole of 51.17 sq. ft. in the inner bottom. The plates near the 4th frame near the outer bottom were broken and very much indented. But little damage was done inboards, while the fore-and-aft and the athwartship bulkheads were uninjured.
1875. Aug. 7.	8	654.5 lbs. of Gunpowder in an iron case ¼" thick. Ignited by 2 Electric fuzes with 385 grains of Gunpowder.	29.2' in 65.' of water.	21.5'	32.5'	45.9'	40.2'	36'	13.56'	17"	Opposite the 5th frame.	Ship rolled to port and was very wet inboard. The water rose 2.8" in the large space amidships and some water leaked in the target from inboard through some opened seams caused by the violence of the shock of the explosion upon the wooden hull. The iron target was uninjured. A distorted piece of the charge chamber case was found on deck.
Aug. 10.	9	18.7 lbs. of Dynamite. In a steel cylinder with convex ends. Ignited by 23 grs. of fulminate with 925.8 grs. Dyn.	9.4'	7.97'	10.46'	31.16'	24.4'	13.1'	13.64'	3.5"	Opposite the 3rd frame.	No leak of any importance could be found. The outer bottom was indented on both sides of the 3rd frame between the 2nd and 4th frames; one indentation extended down about 8' from 7.8" above the water line; the other from 2.2' above the water line to 7 feet below the water line. These indentations were 1⅛' and 1½" deep respectively. The plates along the 4th frame had a crack 3.9' long. One rivet was stripped.
Aug. 10.	10	As No. 9.	9.4'	-.97'	3.4'	22.1'	15.6'	8.53'	13.64'	3.5"	Opposite the 7th frame.	Ship listed to starboard and was docked. The outer bottom had an indentation 7.8' broad by 6.8' high which terminated in an irregular hole of about 23 sq. ft. This was above the 2nd string-piece between the 6th and 8th frames. The outer bottom was also indented below the 2nd string-piece for a space 13.64' long and 4.88' wide, and had two cracks 9.7' and 12.65' long and several inches wide. The frames were bent and the 7th frame was partly carried away. The inner bottom was slightly indented and had a small crack. The target was not completely breached.
Nov. 30.	11	112.2 lbs. of Gunpowd'r. Iron case ¾" thick. Ignited by 2 Ebner's fuzes with .35 lbs. of powder in a glass tube.	10.5'	-2.8"	5.1'	22.6'	15.84'	16.4'	13.5'	13.4"	Opposite the 5th frame.	The target was found full of water five minutes after the explosion. The ship was docked at once. 35.1 sq. ft. of the outer bottom was completely carried away above the 2nd stringpiece, and the inner bottom was breached at this part slightly. Both bottoms were carried away below the 2nd stringpiece. The hole in the outer bottom measured 72 sq. ft., and that of the inner bottom 57 sq. ft. The wing passage bulkhead was bent in and broken. Some angle irons were displaced.
1876. Sept. 12.	12	654.5 lbs. of Gunpowd'r. In a steel cylinder ¼" thick, convex ends, Ignited by two Ebner's fuzes with .28 lbs. of powder in a glass tube.	29.2'	4.83'	23.55'	31.15'	27.1'	28.24'	13.4'	17.7"	Opposite the 5th frame.	The ship was lifted bodily and careened over to starboard. The iron deck was carried away and had a hole of about 100 sq. ft. The wooden deck and the ship itself was hogged. The beams were carried away and the ship's sides tumbled out so that she could not be docked. The target was completely breached, the hole in the outer bottom meaaured 64.6 sq. ft. and that in the inner bottom was 71 sq. ft. The 6th frame was carried away and the 4th and 7th were bent. The wing passage bulkhead was bursted and stanchions and connections were knocked down. The ship was virtually destroyed.

* The list to port is given in inches, showing how many inches the starboard side was raised out of water by the list to port.

The first series proves that the depth at which a mass thrown out by an explosive loses its breaking force is 1.34 R. It was intended to prove this by experiments upon ice but opportunity failed.

Class B.

These were the chief experiments of the series, and the Swedish government placed a ship of the line, the Foersigtigheten, at the disposal of the Board for this purpose.

The ship was cut down to the line of the lower gun deck ports amidships, and nearly to the light load line at the extremities. She was 177.1′ long at the water line, 49.6′ beam amidships. The draught was 19.9′ forward and 21.4′ aft. A hole was cut out of the starboard side on both sides of the midship frame which was 31.1′ long and 24.3′ high. This hole extended from 4.13′ below the light load line to within 6.56′ of the keel. An iron target was fitted to this hole which was made in all respects like a section of the double bottom of the English ironclad Hercules. The two bottoms were 3′ apart. The plates of the outer bottom were $\frac{7}{8}''$ thick, decreasing to 13-16″ and $\frac{3}{4}''$ in the upper part. The plates of the inner bottom were $\frac{1}{2}''$ thick.

There were nine iron frames and five stringpieces between the two bottoms, the two outer frames and the highest and lowest stringpieces being at the edges of the target. The frames were numbered from forward, from No. 1 to No. 9, and the stringpieces from above, from No. 1 to No. 5. The frames were 4′ apart; the two upper stringpieces were 9′ apart and the others 4.5′ apart. The target had a centre frame with bracket plates and was made water-tight above the second stringpieces. The space between the two bottoms was thus divided into four separate water-tight compartments.

The space behind the target was closed by a vertical iron bulkhead of $\frac{1}{2}'$ plate, which was joined to two athwartship bulkheads extending from the forward and after edges of the target to the opposite sides of the ship. It was covered in by an iron deck 7-16 in. thick and was subdivided into four water-tight compartments by bulkheads in the wing passages and by athwartship bulkheads from the centre frame of the inner bottom to the fore and aft bulkhead. Iron doors were fitted to these, and man-hole plates to the compartments in the target proper, which was joined to the wooden hull by screw bolts, iron plates and angle irons. In order to make the ship resist the heaviest shocks, two rows of timbers were placed on deck to confine the ship's sides;

these ran across from side to side for the whole length of the ship. Additional supports were also given to the deck directly over the target. The hull was thoroughly caulked and six hundred and thirty water casks, of 9.34 cubic feet each, were stowed under the berth deck, in the forward and after extremities of the ship. Six pumps were fitted to the spaces in the target, and four to those behind it. Two valves were fitted to the wooden hull so that the ship could be sunk to any depth desired. The preparations were completed on the 18th of September, 1874, when the ship was taken out of the dock and anchored in the harbor of Carlskrona. The draught of the ship as here given was only when on an even keel; but when listed over to port, as was usually the case, the draught was much greater amidships.

The mines were directed so as to explode opposite the centre of the target, and as far as to the centre of the forward and after parts; and the greatest care was taken to explode them at the several distances calculated for each mine. The mines were generally suspended from a boom rigged out above the third, fifth and seventh frames, so as to be opposite the centre of the forward half, the center of the target, and the centre of the after half, respectively, as desired. In some cases the mines were suspended from hooks at the water line, and in one case it was secured to a shelf built upon the target itself.

The harbor of Carlskrona being free from currents was most favorable for the experiments. Various kinds of pressure gauges were used to ascertain the lifting force or work developed by an explosion in breaching the target. English crusher gauges were employed, similar to those used in the Oberon experiments, secured to the outer bottom of the target; they proved unsatisfactory, being too delicate to give regular indications. A style of gauge based upon the compression of spiral springs was then tried, it also proved unsatisfactory; but a modification of the French gauge invented by Captain Vavin was tolerably accurate.

Full details of these experiments are given in the following tables. Of these experiments eight out of the first ten were made with dynamite mines at a depth of 9.8′, to prove the law expressed by the equation $R = 5.5 \sqrt[3]{L}$. From these the Board concluded that the resistance of the strongest part of the target, or m, was less than 13.4′ and greater than 10.4′ in the cases where the target was breached. (No's 7 and 10).

In deducing the coëfficient 5.5 for dynamite, that for gun cotton was found to be equal to 5.35 ; but recent information makes wet gun-cotton quite as strong as dynamite so that the Board concluded to take a mean of these two and consider the two explosives as equal. The equation then becomes $R = 5.43, \sqrt[3]{L}$ for dynamite or gun cotton.

In the eleventh experiment the mine was suspended by a chain from a hook in the upper part of the target, with an immersion of 10.5′, and kept in this position by means of guys passed under the keel to the port side of the ship. The case was turned with its weakest part —the line of joints in the cylindrical shell—towards the target. The charge was placed in a charge-chamber, leaving a considerable unoccupied space in the mine case. Pressure cases, besides the usual pressure gauges previously mentioned, were placed around the mine in three directions to ascertain for this explosion a characteristic number such as was used in the igniting experiments. This characteristic was found to be but 50, though it completely breached the target, the loss of force being caused by the air space in the mine. The lowest edge of the breach was below the mine's centre, and the breach generally indicated that the line of least resistance passed through the outer bottom to the air space between the two bottoms, as does also the very small column of water thrown up. The target was then docked and extensively repaired, as usual after each experiment.

The twelfth experiment was made on the 12th of September, 1876, in the presence of the King of Sweden and Norway. In this, 654.5 lbs. of musket powder were placed in a buoyant case of $\frac{1}{4}$ in. steel plate fitted with an inner charge case of 1-16 inch steel plate. The case was suspended from a boom rigged out above the centre of the target and had an immersion of 29.2′. Pressure cases and gauges were suspended around the mine as before, and various kinds of empty mine cases and circuit closing apparatus were exposed in the water to give some idea of the indirect effects resulting from such a large charge. This explosion should have a characteristic of about 90.

The ship was almost completely destroyed by this explosion,—her sides tumbled out, beams and knees were carried away, and the decks were hogged so that the ship could not be docked having spread to a width greater than that of the dock gates.

The four experiments with gunpowder mines prove the correctness of the equation $R = 3.65\sqrt[3]{L}$. These experiments were made to ascertain the size of the charge that may be exploded with safety in a spar torpedo 25′ horizontally distant with 10 immersion ; vide numbers 1 and

2; secondly, to prove the general law for dynamite and gunpowder; thirdly, to see what charge may be established as the minimum for contact mines;—this was shown from the tenth experiment to be not less than 18.7 lbs. of dynamite. In this an allowance is made for a distance of 3′ or 4′ owing to the difficulty of insuring absolute contact at the instant of explosion;—and finally, to ascertain the value of the resistance of a modern double bottom man-of-war in terms of the distance or the length of the radii of explosion. See table.

Class C. Experiments with Armor.

These were made at Copenhagen in December, 1874, in order to ascertain the effects on an ironclad ship's side when dynamite or guncotton mines are exploded near the surface of the water close to the armor; they would also determine the size of the charge necessary for offensive mines, such as spar, towing, and Whitehead, or fish torpedoes.

The Board made a preliminary investigation of the results of a series of experiments which had been made in Austria with plates of one square foot surface and varying thickness up to three inches. From these experiments Captain Lauer of the Austrian Engineers deduced a simple formula, according to which the charge of dynamite or guncotton necessary to breach a freely exposed plate of iron one foot square depends upon the equation $L = d^2$, where $L =$ the required charge, and $d =$ the thickness of the iron plate in inches. When the surface alters, the charge varies or $L : L' = b \times d^2 : b' \times d^2$: provided that the charge is distributed over the surface of the plate with a thickness one and a half times that of the plate, and that the dynamite has 75 per cent. of nitro glycerine and a specific gravity of 1.5.

The Board made fourteen introductory experiments to prove Lauer's formula. The charges were not distributed equally over the entire surfaces but used in cylinders, parallelopipeds, and other forms so that they might answer to the shapes of the offensive mines generally used. They were placed in paper, wooden, and tin cases, upon the plates freely exposed on the ground, or supported by a wooden foundation resting on piles driven into the ground. These experiments were made behind the breastworks of the fortifications at Copenhagen. In some cases the mines were covered by 8.3″ of loose earth, equivalent to a confinement of 1.3′ of water, because offensive mines do not explode at the surface but at some distance below.

From the first ten experiments the formula was found to indicate a greater charge than that absolutely necessary to breach. When a

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CLASS C.

Experiments with Iron Plates. Copenhagen, 1874.

Date.	Number.	Thickness.	Surface of the Plate. (The Iron Plates.)	The Foundation. (The Iron Plates.)	Weight in lbs. (The Charge of Dynamite.)	Kind of Case.	Internal Dimensions of the Case.	Position of the Mine.	Confinem'nt.	Effects.	Remarks.
Dec. 5.	1	½''	12.36''×12.36''	11.3'' freely expos'd on 2 wood beams.	.275	Paper case rectang'lar	1.03''×2.5 '×2.5''	At the Centre.	None.	Completely broken.	The cylindrical charges were placed on end in the 2d, 4th, and 7th experiments.
"	2	1''	"	"	1.1	Cylinder Paper.	2.05''×3.7'' dia.	" "	"	Broken into 4 pieces.	
"	3	½''	"	Complete foundation of 6.3'' timber.	1.1	rectang'lar Paper.	1.9''×3.7''×3,7''	" "	"	Breached and driven through the piles,	
8	4	1''	"	11.3'' freely exposed on 2 wooden beams.	.55	Cylinder Paper.	1.3''×3.56 dia.	" "	"	Bent and breached with a star shaped hole.	Small charges of dynamite placed about 2' or 3' from the 4.4 lb. mine, were detonated by the 14th explosion.
8	5	½''	"	Bolted by 4 bolts to 8.3'' timber.	.275	Rectang'lar Paper.	1.03''×2.5''×2.5''	" "	"	Bent and broken at the centre.	
"	6	1''	"	On the end of a vertical beam 8.3'' thick.	1.65	"	2.14''×4.37''×4.37''	" "	"	Not breached but bent into a star shaped crack.	
"	7	1''	"	Bolted by 4 bolts to 8.3 timber.	2.2	Cylinder Paper.	2.57''×5.2'' dia.	" "	"	3 pieces, timber crushed.	4 cartridges of 2 lbs. of dynamite were placed at distances of 10', 15', 20', & 25' from the 18th & 19th mines but were not affected by the explosion.
"	8	½''	"	On the end of a vertical beam 8.3'' thick.	1.1	Rectang'lar Paper.	1.9''×3.7''×3.7''	" "	"	In 2 pieces, & breached. Timbers split.	
9	9	1''	"	Complete foundation of 8.3'' timber.	1.65	"	2.14''×4.37'' ×4.37''	" "	8.3 of earth.	Broken into 3 pieces.	
"	10	1''	"	Complete foundation of 8.3'' timber.	1.1	"	1.9''×3.7''×3.7''	" "	"	Bent and broken but not breached.	
10	11	½''	2.06'×2.06'	6.3'' beams with the earth packed supporting foundation of 8.3'' timber.	1.65	"	1.54''×5.14''×5.14''	" "	"	In 3 pieces. Foundation crushed.	5 cartridges of 2 lbs. each were exposed at distances of 10', 15', 20', 25', & 30', in the last 2 exp. but were not exploded.
"	12	1''	"	"	3.3	Rectang'lar wood'ncase	2.28''×5.67''×5.67''	" "	"	In 4 pieces. Foundation crushed.	
"	13	½''	"	"	2.2	"	1.94''×5.14''×5.14''	" "	None.	Breached by a hole 9.4'' in diameter. Timber broken.	
"	14	1''	"	"	4.4	"	2.64''×6.33''×6.33''	" "	"	Breached by a hole of 78 square inches.	
"	15	2''	2.06'×2.57'	Same as before with the beams resting on 4 piles 38.4''□ cross section.	8.8	"	4.28''×7.2''×7.2''	" "	"	Breached by a small hole in the centre of an indentation of 2.6 sq. ft.	
"	16	2''	"	"	8.8	"	4''×5.1''×10.2''	1 end in contact the other 3'' from plate.	8.3'' of loose earth	In 3 pieces. Timber foundation was crush'd	
"	17	2½''	2.28×5.6'	As no. 15, but resting on 6 piles.	1.1	"	4.23''×5.14''×5.14''	1 end 2.05,'' the other 5.14'' from the plate.	"	Broken in 4 pieces.	
12	18	2½''	2.14'×4.63'	"	16.5	"	3.08''×8.48''×16.47''	" "	"	In 6 pieces. Foundation crushed.	
	19	5''	3.17'×4.72'	As no. 15, on 8 piles with the plate screwed to the timber.	44.	Wooden case like the Harvey	4.12''×13 38''×2.16''	1 end 2.05'' the other 5.66'' from the plate.	"	Bent in the middle. Foundation completely crushed.	
15	20	"	Same plate.	Placed as bent resting on 2 pieces of timber.	44	Tin cylinder.	24.72''×7.72'' dia.	charge 10'' from one side edge.	"	One corner broken off.	
15	21	"	Same plate.	Placed vertically as thrown.	44.	"	18.53''×8.72'' dia.	Covered with 8.3'' loose earth. Packed earth behind plate.	"	In 4 pieces, 2 of which were thrown to a distance of 410.	
16	22	5''	3.85'×5.64'	Resting on 8.3'' timber on 4 cross pieces supported by 6 piles, and pieces of timber at the sides.	55.	Cylindro-conical case of tin.	8.13''×15.43''×5.14''	With its peak towards the centre of the plate in contact.	"	The plates were slightly bent and torn from the foundation but the foundation was not crushed.	
"	23	5''	3.47'×4.72'	"	77.	rectang'lar wood'ncase	7.2''×14 4''×18.53''	At the centre in contact.	"	Split in the middle. Foundation crushed.	

charge is confined it may be reduced 25 per cent. and still give the same effect as when not confined, and again it need not be distributed evenly over the entire surface, but may be used with equal effect in various shapes. In the sixteenth, seventeenth, eighteenth, and nineteenth experiments the charge was shaped like the Harvey towing torpedo. In the twenty-second, the charge was intended to represent the Whitehead; but for convenience the case was but 8.2″ long and the cylinder 15.4″ in diameter and 5.1″ long; this brought its centre of gravity 10″ from the plate, while it is 32.5″ from the peak in the Whitehead.

These experiments demonstrate that a spar torpedo, operated from a small torpedo boat, will not seriously damage the heavily armored part of an iron-clad, because this charge will have but little confinement, and will be too small. The same is true of the Harvey and Whitehead, since their shape does not permit the charge to be brought into absolute contact. But it is also seen that the charge which will not breach will often cause serious damage by crushing in the backing of the armor and the ship's frame.

They find that Lauer's formula is generally true so that charges may be approximately deduced from $L = b \times d^2$, where b is a coëfficient depending on the surface of a plate and the support given by the foundation. In general b may be assumed as $= 3 \therefore L = 3d^2$. In this, the thickness of the charge or its measurement perpendicular to the plate must be 1.5 d for dynamite compressed to a density of 1.4, and the charge must be exploded in contact with the plate or very close to it with at least 1′ or 1.5′ immersion. The Board recommends the oblong cylindrical towing torpedo as the most favorable shape for an offensive torpedo. The resistance of plates more than 10″ thick is proportionately less and for these we may reduce the exponent of d to 1.5 and use $L = 3d^{1.5}$.

The experiments show that it will be useless to attempt to breach 5″ armor by 77lbs. of dynamite slightly confined in an offensive torpedo near the surface, since this charge did not breach this plate although it completely crushed its massive foundation. If this charge has any greater immersion, it will the more readily breach the armor, since confined charges are by so much the more powerful. A confinement of 8.3′ of loose earth = 1.3′ of immersion of water gives more than 25 per cent. greater effect; greater depths will increase this much more so that it will be perfectly useless to try to increase the resistance of a ship's bottom by any amount of armor.

Class D. The Countermine Experiments.

The Board made eight experiments in all, four with charges of 224.4lbs., and four with 448.8 lbs. of dynamite. (Four of them only are appended) and from the first four the Board arrives at the following conclusions:

1st. That the effects of countermines are greatly enhanced when at considerable depths.

2nd. That the pressure cases indicate a definite relation of the effects to the distance, which is that the charge varies as the distance raised to the 2.4 power when 9.7′ deep and to the 2.94 power when 29.2′ deep.

3rd. That the pressure gauges were too irregular to afford any means of comparison; probably owing to the fact that the shock imparted by a countermine's explosion is like a blow, while these gauges were adjusted for a gradual pressure.

4th. That the limit of the destructive effect of 448 lbs. of dynamite in the strongest kinds of cases exposed is from 175′ to 195′. In this connection it was seen that the shape of the case exercised a very important influence on its resistance to the shock of the explosion; the spherical shape is the best, but the Board recommends cylindrical cases with convex ends as very strong. Bessemer steel is also recommended as the best material for cases.

5th. That mines of dynamite can be prevented from exploding when exposed to countermines by having elastic cushions between the outer and inner cases and by packing the charge with sawdust between the cartridges and all spaces. Some experiments made in Denmark demonstrated that dynamite mines could be protected by means of water-tight wooden jackets, but the most effective means are dependent upon the distance from the countermine.

The other four experiments with countermines, made in 1875, confirmed the conclusions deduced by the Board from the first four and also established that steel plate offers the greatest resistance to countermines; that contact mines are unaffected when at a distance of 146′; that observation mines are unaffected when at a distance of 175.5′; that the double cone case is the most unfavorable shape; that the spherical case is the best shape, and that the cylinder with convex ends is practically the most suitable and strongest kind of case when the radius of convexity of the ends is at least one third the diameter of the cylinder at its base.

										9	"	9.7′ in 34′ of water	Sperical case, ⅛″ thick with Danish cir. closer apparatus.	152 lbs. of sand.	Found the case to be a trifle damp. No injury.				

CLASS D. THE COUNTERMINE EXPERIMENTS.

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CLASS D.

FIRST EXPERIMENT WITH COUNTERMINES. CARLSKRONA, SEPEEMBER 14, 1874.

Description of the various cases around the Countermine and their effects produced.

Date.	Description of the Countermine.	Depth of the Countermine.	Pressure cases 1/8" thick, 13" high, at a depth of 9.7'. No.	Dis'tance.	Effects k = characteristics.	Pressure Gauges, 9.7 deep. Kind and Numb'r	Dis'tance.	Effects. Movement.	Effects. Pressure.	Different kinds of Cases, &c. No.	Position. Distance.	Position. Depth.	Description.	Charge of Sand.	Effects.	Loaded Mines, 9.7' deep. No.	Distance.	Descript'n.	Effect.
Sept. 14th, In the harbor of Carlskrona when the water was 32.1' to 41' deep.	224.4 lbs. of Dynamite containing 75 per cent. of N. G. In an iron cylinder with convex ends 1/8" thick, 1.93' high, 1.57' diameter, having an igniting charge of .2 lbs. of dynamite and 2 fuzes of 23 grains of fulminate in each.	9.7" deep in 38' of water	1	43 8'	Sides partly deform'd ends driven in so as to become only 12.8" high. k = 60.	1 Harvey bolt.	146'	III IV 5 9 12.5 mm	Absolute. 51.7lbs	1	195'	9.7' in 40' of water	Iron cylinder 1/4" thick, having a capacity for 168 lbs. in an inner zinc charge chamber.	168 lbs. of sand.	Case filled and sank. 2 rivets (inferior) were stripped, causing the leak. The spindle in the case was bent and had an indentation 3/8"	1	58 4'	Iron cylinder 1/8" thick, having an inner charge chamber of oak, 1/2" thick, snugly fitting outer case and containing 23.3 lbs. of dynamite packed in cartridges with sawdust.	The explosion of the countermine exploded this mine.
			2	92.5'	Sides slightly indented about 1/8".	2 Electro Contact lever.	195'	III IV 7 5 16.1 mm	66.6	2	195'	15.6' in 41.' of water	Iron cylinder 3/4" thick, capacity for 654.5 lbs. in an inner charge chamber, 1-12" thick.	654.5 lbs. of sand or sawdust.	The interior of this case was damp, otherwise not affected.	2	"	Iron cylinder 1/8" thick, having an inner zinc charge case fitting with 1" play on all sides, and supported in its place by wooden disks at the bottom and top and by staves on the sides covered with rubber 23.3 lbs. of dynamite were pack'd with sawdust in the inner case.	This was not exploded by the shock of the countermine. Uninjured.
			3	13 8'	" "	3 "	214'	III IV 6 9 14.7 mm	30 lbs. per sq. in.	3	"	41.'	Ground mine case for 654.5 lbs. of gunpowder.		Found 50 cubic inches of water in this case wh. was oth'rwise not damaged.				
			4	19.5'	" " also bent in 1/4"	4 "	"	III IV 3 4 7.4 mm	15 lbs. per sq. in.	4	"	9.7' in 41' of water	Swedish modification of the Chatham circuit closer connected with galvanometer.		No damage and no deflection of the galvanometer needle.				
			5	24.4'	None.	5 "	292'	III IV 6 10 16.2	19 lbs. per sq. in.	5	244'	24.3' in 38' of water	Iron cylinder case, 1/4" thick, for 654.5 lbs. of powder in charge case rivetted to it.	654.5 lbs. of sand.	Uninjured.				
			6	29 2'	None.					6	"	9.7' in 40' of water	Like No. 5, but capacity for 168 lbs. of gunpowder.	168 lbs. of sand.	Uninjured.				
										7	"	9.7' in 34'	Like No 6, sides 1/8", and ends 3-16"	"	One rivet stripped and leaking, but still serviceable.				
										8	292'	9.7' in 32' of water	Like No. 7.	"	Found 70 cubic inches of water in the case whch had received no injury.				
										9	"	9.7' in 34' of water	Sperical case, 1/8" thick with Danish cir. closer apparatus.	152 lbs. of sand.	Found the case to be a trifle damp. No injury.				

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								10	244′	in 39′ of water	Iron cylinder ⅛″ thick. New model.	165	case half full of wat'r, otherwise uninjured.				

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CLASS D.

SECOND EXPERIMENT WITH COUNTERMINES. CARLSKRONA, SEPTEMBER 29, 1874.

Description of the Countermine.	Description of the various kinds of cases around the Countermine.																
	Pressure Cases 13½″ high, at a depth of 9.7′			Pressure Guages.				Different kinds of Cases.						Loaded Mines, 9.7′ deep.			
						Effects.			Position.								
	No.	Distance	Effects. k = characteristic.	No. and Kind.	Distance and Depth.	Movm't	Pres.	No.	Dist	Depth	Description.	Ch'ge of Sand.	Effects.	No.	Dist.	Description.	Effect
224.5 lbs. of Dynamite in an iron cylinder with convex ends ⅛″ thick 1.94′ high, 1.57′ diameter, With an igniting charge of .2 lbs. of Dynamite, with 2 fuzes of 23 grs. of fulminate of mercury 29.2′ deep in 41′ of water	1	39.2′	Sides and ends c'mpl'tely deformed. Height = 8″ k = 100.	Nos. 1 and 2 Ekerman's make.	146′ from the mine, and 21.2′ deep.		Atmos. No. 1= 11⅔. No, 2 = 14.	1	146′	24.3′ in 40′ of water	Iron cylinder ⅜″ Experimental case for 654.5 lbs. of powder in an inner chamber.	6545	A little wet. Charge case dry. Sides and bottom ind'nt'd. Still serviceable.	1	61.5′	Iron cylinder ⅛″ th'k with an inner iron ch'rge case fitting with 1″ play on all sides held by oak staves covered with rubber. Loaded with 23.3 lbs. of dynamite packed in cartridges with sawdust.	None
	2	70.8′	One side slightly indented. H'ght = 13⅛″ k = 35	No. 3. Ekerman's make.	194.8′ fr'm mine 7.8′ deep.		< 5 Atmospheres.	2	148′	40′	Ground mine case serving as the anchor for No. 1.	None	Case severed and broken in two. A large piece was knocked out of bott'm				
	2	52.5′	Sides deformed. Ends bent in 1⅛″ sides, 4″ Height = 12″ k = 75.	No. 4. Danish Harvey Bolt.	292′ from mine, 9.7′ deep.	III. 5 10 mm.	Absolute pr's sure of 48.4 lbs.	3	150′	9.7′ in 40′ of water	Silvertown Circuit Closer Apparatus in a wooden box, connected by wires to batt'ry galvanometer, etc.	None	Galvanometer not deflected.				
	4	90′	H'ght=13¼″ Bottom indented 1″ sides 13-16″ k = 15.	No. 5. Like No. 4. No. 6, do.	390′ distant and 9.7′ deep.	III. IV. 2. 8. 5.6 mm. III. IV. 2. IV. 5.4 mm.	13.06 lbs per sq. in. 11.95 lbs per sq. in.	4	196′	9.7′ in 39′ of water	Iron cylinder ¼″ thick, with center spindle and braces screwed in and made tight by hemp packing.	165	Tight and serviceable. Spindle bent and braces torn out. Cast iron shoes bkn off	2	"	Iron case ⅛″ thick with an inner case loaded with 18.7 lbs. of dyn'mite in cartridges pack'd with sawdust in all spaces.	None
	5	138.6′	H'ght=13¼″ Bottom indented ½″ Sides ⅝″ k = 5.	No. 7, do. No. 8, do.	585′ distant and 9.7′ deep.	III. 2 4.2 mm. III. IV. 1. 4. 3 mm.	8.24 lbs. per sq. in. 10.79 lbs per sq. in.	5	196′	21.8′ in 35′	Iron cylinder ¼″ thick. Experimental model for 654.5 lbs. of powder.	6545	Case serviceable but indented at sides. Spindle bent in.				
								6	196′	9.7′ in 39′	Iron cylinder ¼″ thick. Danish model. Wrought iron shoes. Spindle strengthened by iron bands.	165	Tight and in order.				
								7	"	9.7′ in 40′	Iron cylinder ¼″ thick, for a charge of 654.5 of powder.	654.5	Tight and in order.				
								8	"	"	Iron cylinder ⅛″ thick. For 165 lbs. of powder. Supported at centre and the sides. Oaken staves to wedge it tight.	165	Case sank. 5 rivets were stripp'd, bottom indented and joints loosened.				
								9	"	9.7′ in 35′	Spherical case iron ⅛″ thick. Experimental model.	150	In order. Bolts at j'ints loosened.				
								10	244′	9.7′ in 39′ of water	Iron cylinder ⅛″ thick. New model.	165	Two rivets stripped and case half full of wat'r, otherwise uninjured.				

CLASS D.

THIRD EXPERIMENT WITH COUNTERMINES. CARLSKRONA, OCTOBER 2, 1874.

Description of the Countermine.

448.8 lbs. of dynamite, 75 per cent. of Nitro Glycerine in an iron cylinder with c'nvex ends ⅜'' thick, 2.43' high, .2' diameter. With an igniting ch'ge of .2 lbs. of dynamite with 2 fuzes of 23 grs. of fulminate each.

9.7' deep in 37' of water.

Description of the various kinds of Cases around the Countermine.

Pressure Cases, ⅜'' thick, 13½' high and 9.7 deep.

No.	Distance	Effects. k = characteristic.
1	48.5'	Bursted and sunk.
2	58.4'	Sides very much deformed. Sides bent in 1¾'' Ends bent in 1½'' Height = 13 1-16'' k = 68.
3	68.2'	Sides deformed, bent in 1 7-16'' Ends bent in 1⅛'' Height = 13⅜'' k = 40.
4	78'	Sides slightly deformed and bent in 1 3-16'' Ends bent in 1 1-16'' Height = 13 5-16'' k = 25.
5	97.3'	Sides not deformed. Bent in 9-16'' Ends bent in ½'' Height unaltered. k = 5

Pressure Guages, 9.7 deep.

No. and Kind.	Dist.	Effects. Movm't	Effects. Pres.
1 Ekerman's.	97.3'		Atmos. 12½.
2 do.	149'		9¾
3 do.	196'		5
4 Bolt of the Harvey To'p'do	389'	III. IV. 3. 5. 7.8 mm.	Absolute. 41.8 lbs.
5 Danish Har v'y Bolt	487'	IV. 10 1.8 mm.	8.24 lbs. per sq. in.
6 do.	"	"	9.37 lbs. per sq. in.
7 do.	682'	IV. 7. 1.2 mm.	7.67 lbs. per sq. in.
8 do.	"	IV. 3. .9 mm.	8.24 lbs. per sq. in.

Different kinds of Cases.

No.	Position. Dist	Position. Depth	Description.	Ch'ge of Sand.	Effects.
1	149'	9.7'	Silvertown Circuit Cl'ser in an ir'n case ⅛'' thick with a wooden jacket. Connected with galvanometer, etc.	None	Damag'd Needle deflected to 15°
2	389'	39'	Danish polarized relay on the bottom.	None	In order.
3	"	at the surface nearly.	Danish Harvey Case. Iron Case with wooden frame at the sides & bottom.	Fill'd with sand and sawdust.	Uninjured.
4	"	"	Swedish H'rv'y case in a wooden box.	"	"

Loaded Mines 9.7' deep.

No.	Dist.	Description.	Effect
1	58.4	A Pressure Case of ir'n ⅜'' thick. Loaded with 37.4 lbs. of gunpowd'r and fitted with a service fuze.	Not exploded Sides defo'med like the 3d pressure case in this experiment. Sides bent in 1 13-16'' Bottom bent in ⅞'' Height unaltered.

REMARKS.

The countermine was anchored by a 1000 lb. mushroom anchor. The explosion forced this anchor 12' into the bed of the harbor, which was of blue clay with 1' or 2' of mud over it.

It required a force of 6500 lbs. measured by a dynamometer to raise this anchor and two chain straps ⅜'' broke in the effort to do so.

CLASS D.

FOURTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, OCTOBER 13, 1874.

Description of the Countermine.	Description of the various kinds of Cases around the Countermine.																
	Pressure Cases, ⅛ thick, 13.5 high and 9.7 deep.			Pressure Guages 9.7 deep.				Different kinds of Cases.						Loaded Mines 9.7 deep.			
	No.	Distance	Effects. k = characteristic.	No. and Kind.	Dist.	Effects. Movm't	Effects. Pres.	No.	Position. Dist	Position. Depth	Description.	Ch'ge of Sand.	Effects.	No.	Dist.	Description.	Effect
448.8 lbs. of Dynamite of 75 per cent. nitro glycerine in an iron cylinder with convex ends ⅛" thick, 2.43' high, 2' in diameter with an igniting charge of .2 lbs. of dynamite with 2 fuzes of 23 grains of fulminate each. 29.2' deep in 40' of water	1	49.3'	Sides pressed together and badly deformed. Bottom loosened and distorted. Head irregularly deformed. Height = 10" k = 97	No. 1 Ekerman's.	97.3'		Atmospheres. 12	1	175'	9.7' in 28' of wat'r	Iron sphere ⅛" thick.	150 lbs.	Case serviceable but had about 2 qts. of water in it. One bolt at the joints broken, solder loosened. Case but little indented.	1	58'	Pressure case of iron ⅛" thick load'd with 23.3 lbs of wet gun cotton with 28 per cent. of moisture with an igniting charge of 1.5 lbs. of dry gun cotton in a tin case with 23 grains of fulminate.	Case sank but was not exploded. Bott'm was badly bent in, sides partially deformed. Height = 12¾". The fuze case was badly bent.
	2	68.1'	Sides badly deformed and pressed together. Bottom knocked out. Top bent in 2¼" Height = 12½" k = 85	2 do.	146'		Atmos. 9	2	"	9.7 in 28' of wat'r	Iron cylinder ¼" thick. Swedish model.	165 lbs.	Case serviceable but had a little water in it. Sides unaltered & tight, the bottom was loose. Spindle & braces bent. All cast iron shoes were loosened.				
	3	89.5'	Sides partly deformed. Head bent in 1 15-16" Bott'm bent in 1" Height = 12⅞" k = 68	3 do.	195'		" 7½	3	195'	40'	Cast iron Ground mine. Swedish model.		Broken badly with the bottom severed at the joints.				
	4	113'	Sides but slightly & partially deformed. Head bent in 2". Bottom bent in 1⅛ Height unaltered k = 25.	4 Danish bolt	389.2	III IV 2—2 4.5 mm.	11.2 lb. per sq. in.	4	"	2'	Danish Harvey Case.	Saw-dust.	Leak in the filling hole—uninjured.				
	5	146'	Sides & Height unaltered. Head bent in 1⅛" Bottom bent in 1" k = 10	5 do.	"	III IV 2—2 4.2 mm.	11.36 lb. per sq. in.	5	"	"	Swedish do.	"	Uninjured.				
				6 do.	584'	III IV O—7 1.2 mm.	7.67 lbs. per sq. in.	6	292'	40	Relay case Danish.		In order after the explosion.				
				7 do.	"	1 III 2.1 mm.	7.67 lbs. per sq. in.										

CLASS D.

2	"	"	"	.22	with the joints loosened at one part of the top.
3	"	"	"	.28	Top severed and crushed in, slightly deforming the sides.
4	"	"	"	.33	One side slightly indented.
5	"	"	Like the steel case describ-ed ab've with the Circuit Closer.	.39	" "
6	"	"	Double cone with spherical ends.		Sides deformed. Larger sphere at the top was broken out. Lower sphere unaltered.
7	"	"	Steel sphere ⅛" thick (could not make steel sphere 1-16" thick.)		None.

CLASS D.

FIFTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST 16, 1875.

Description of the various kinds of cases around the Countermines.

Description of the Countermine: 244.4 lbs. of dynamite, 75 per cent. Nitro-Glycerine. In an iron cylinder with convex ends ⅛'' thick 23'' high, 19'' diameter, with igniting charge of 2 lbs. of dynamite with 2 fuzes of 23 grs. of fulminate each. 9.7' deep in 39' of water

Pressure Cases, ⅛'' thick, 13.5'' high, 9.7' deep.

No.	Distance	Effects. k = characteristic.
1	39'	Sides deformed sides indented 1.58''. Bottom indented, 1.25'' Height=12.56'' k=60.
2	48.7'	Case partly deform'd sides indented, 1.35'' Bottom indented .97'' Height unaltered k=40.
3	58.4'	Sides slightly deformed, sides indented .94'' Bottom indented .67'' Height unaltered, k=20.
4	68'	Not deformed, Sides indented 47'' Bottom indented .47'' Height unaltered k=3.
5	78'	Not deformed, Sides indented 1 13'' Bottom indented .51'' Height unaltered k=8

Pressure Gauges.

Kind and Number.	Dist.	Depth.	Effects Indicated.
Swedish			Atmospheres
No. 6	39'	9.7'	(24)
" 7	"	"	6
" 1	"	29.2'	10
" 3	58.4'	9.7'	0
" 8	"	"	0
" 2	"	29.2'	5
" 4	78	9.7'	5
" 5	"	"	2
" 9	"	29.2'	22
French			Compression
No. 1	39'	9.7'	9 m.m. =.35''
" 4	"	29.2'	10.5 " =.41''
" 6	58.4'	9.7'	4 " =.16''
" 2	"	29.2'	6 " =.24''
" 5	78'	9.7'	3.25 " =.13''
" 3	Omitted.		

Different kinds and shapes of Cases.

No.	Distance	Depth.	Description.	Charge of Sand.	Effects.
1	146'	9.7' in 39' of water	Steel cylinder 3-16'' thick with convex ends, having an inner charge chamber fitted for a charge of 164 lbs., and filled with sawdust, and a Silvertown Circuit Closer connected with galvanometer, etc. Board's Model, 1875.	164 lbs. of sand and sawdust.	Case uninjured. Galvanomet'r needle not deflected.
2	"	29.2' in 39' of water	Steel cylinder ¼'' thick with convex ends, with an inner cylindrical case of steel 1-16'' thick, for 654.5 lbs. of powder, case filled with sand and sawdust. This was anchored by a ground mine case filled with water.	654 5 lbs of sand and sawdust.	Case uninjured.

No.	Distance	9.7'	Experim'ntal shapes of steel cases 1-16'' thick, with a vol'me =1220 cu. in.	Ratio betw. the height and diameter of convex ends.	Effects.
1	68'	9.7'	Cylinder with convex ends.	.16	One side slightly indented, one indentation in the top, two in the bottom.
2	"	"	"	.22	Slightly deformed, with the joints loosened at one part of the top.
3	"	"	"	.28	Top severed and crushed in, slightly deforming the sides.
4	"	"	"	.33	One side slightly indented.
5	"	"	Like the steel case describ-ed ab'ye with the Circuit Closer.	.39	" "
6	"	"	Double cone with spherical ends.		Sides deformed. Larger sphere at the top was broken out. Lower sphere unaltered.
7	"	"	Steel sphere ⅛'' thick (could not make steel sphere 1-16'' thick.)		None.

CLASS D

in 38 of water.

			dust. Anchored by a ground mine case filled with water.		indrical part were loosened, iron bands were bent and the mooring chain damaged.

No.	Distance	D'pth	Experimental shape of steel cases 1-16'' thick with a volume = 1,220 cub. in.	Ratio of the height & the diameter of the ends.	Effects.
4	68	9.7'	Cylinder with convex ends.	.33	Sides rather badly deformed, along the joints of the ends. Bottom unaltered except that due to the sides being crushed.
5	"	"	Like the steel case described above with cir. closer.	.39	" "
6	"	"	Doubled Cone.		Badly deformed.
7	"	"	Steel sphere ⅛'' thick.		None.

CLASS D.

SIXTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST, 18, 1875.

Description of the various kinds of cases around the Countermines.

Description of the Countermine.	Pressure Cases, ⅛″ thick, 13.5″ high, 9.7′ deep. No.	Distance	Effects. k = characteristic.
224.4 lbs. of dynamite, 75 per cent. of Nitro glycerine in an iron cylinder ⅛″ thick, 23″ high, 19″ diameter. With an igniting charge of .2 lb. of dynamite with 2 fuzes of 23 grains of fulminate each. 29.2′ deep in 38 of water.	1	39′	Badly deformed. Top knocked in and broken. Bottom severed and bent. Height = 11.97″ k = 90.
	2	48.7′	Badly deformed Sides indented 2.13″ Bottom knocked in Height = 12.36″ k = 80.
	3	58.4′	Deformed. Sides indented 1.55″ Bottom knocked in. Height unaltered. k = 65.
	4	68	Not deformed. Sides indented 1.26.″ Bottom indented. 1.06″ Height unaltered. k = 20.

Pressure Gauges.

Kind and Number.	Dist.	Depth.	Effects Indicated.
Swedish.			Atmospherès.
No. 8.	39′	9.7′	11.5
" 1.	"	29.2′	19
" 2.	"	"	27
" 5.	58.4′	9.7′	9
" 3.	"	29.2′	15
" 4.	"	"	18
" 6.	78′	9.7′	7
" 7.	"	29.2	9.5
" 9.	"	"	(17)
French.			Compression.
No. 4.	39′	97′	12.25 mm.=.48″
" 1.	"	29.2′	
" 6.	58.4′	9.7′	7 = .27″
" 3.	"	29.2	8.75=.34″
" 5.	78′	9.7′	4 = .16″
" 2.	"	29.2	8=.32

Different kinds and shapes of Cases.

No.	Distance	Depth.	Description.	Charge of Sand or Sawdust.	Effects.
1	146′	9.7′ in 37′ of wat'r	Steel cylinder 3-18″ thick with convex ends, having an inner charge chamber for 164 lb charges, filled with sawdust, and fitted with Silverton Circuit closer, galvanometer fuze etc., Boarts Model, 1875.	164. lb. of sand & sawdust.	In order. Circuit closer apparatus was not affected.
2	"	29.2′ in 37′ of wat'r	Steel cylinder ¼″ thick with convex ends, and an inner steel case 1-16″ thick, fitted for 654.5 lbs. charge filled with sand and sawdust. Anchored by a ground mine case filled with water.	654.5 lbs of sand and sawdust.	Half full of water— charge case damp. Sides indented near the ends ⅓″ deep, 3″ long. An indentation on the bottom 7″ long—5″ broad and ½″ deep. Joints in the cylindrical part were loosened, iron bands were bent and the mooring chain damaged.

No.	Distance	D'pth	Experimental shape of steel cases 1-16″ thick with a volume = 1,220 cub. in.	Ratio of the height & the diameter of the ends.	Effects.
4	68	9.7′	Cylinder with convex ends.	.33	Sides rather badly deformed, along the joints of the ends. Bottom unaltered except that due to the sides being crushed.
5	"	"	Like the steel case described above with cir. closer.	.39	" "
6	"	"	Doubled Cone.		Badly deformed.
7	"	"	Steel sphere ⅛″ thick.		None.

Seventh Experiment with Countermines. Carlskrona, August 24, 1875.

Description of the various kinds of cases around the Countermine.

Pressure Cases, ⅛″ thick, 13.5″ high, 9.7′ deep.

Description of the Countermine.	No.	Distance.	Affects. k = characteristic
448.8 lbs. of Dynamite of 75 per cent. of Nitro-Glycerine. In an iron cylinder with convex ends ⅛″ thick 29.1″ high 24.4″ diameter, with an ignition charge of 2 lbs. of dynamite with 2 fuzes of 23 grains of fulminate each. 9.7′ deep in 39′ of water.	1	48.7′	Badly deformed, sides indented 2.2″ and split. Bottom knocked in and half severed. Height=12.5″ k=85
	2	58.4	Deformed most on one side, indented 1.4′ Bottom knocked in and partly severed. Height = 12.9″ k = 65.
	3	63′	⅔ of the shell of the case deformed. Indented 1.32″ Bottom partly severed. Height unaltered k = 60.
	4	78′	Not deformed. Indented .93″ Bottom loosened. Height unaltered k = 10.
	5	97.′4	Indented .68″ Bottom loosened Height unaltered k = 8.

Pressure Gauge.

Kind and Number.	Dist.	Depth.	Effects Indicated
Swedish.			Atmospheres.
No. 1.	48.7′	9.7′	10
" 2.	"	"	15
" 5.	"	29.2′	16
" 3.	58.4′	9.7′	5¾
" 4.	"	"	9
" 7.	"	29.2	15
" 6.	78′	9.7	7
" 9.	"	"	(9)
" 8.	"	29.2	6¾
French.			Compression.
No. 2.	48.7′	9.7′	14.75 mm. = .58″
" 4.	"	29.2	17 " = .67″
" 3.	58.4′	9.7	8 " = .32″
" 5.	"	29.2	13.25 " = .52″
" 1.	78′	9.7	5 " = 1.97 ′
" 6.	"	29.2	8.75 " = .34″

Different kinds and shapes of mine cases.

No.	Distance	Depth.	Description	Charge of Sand or Saw-dust.	Effects.
1	146′	9.7′ in 38′ of wat'r	Steel cylinder 3-16″ thick with convex ends, having an inner charge case for 164.4 lbs. of charge and fitted with the Silvertown circuit closer, galvanometer fuze, etc., case filled with sand and sawdust, Brush's Model, 1875.	164.4 lbs of sand and saw-dust.	Case in order. Circuit closer did not make contact.
2	175.5′	29.2′ in 38′ of wat'r	Steel cylinder ¼″ thick, with convex ends, having an inner steel charge case 1-16″ thick armored by means of a ground mine filled with water. Capacity of this case was 654.5 lbs., and was filled with sand and sawdust.	654.5 lbs of sand and saw-dust.	In order.

No.	Dist.	Depth.	Experimental shapes of steel cases.	Ratio of the height of ends to diam'r of base.	Effects.
1	48.7′	9.7′	Steel sphere ⅛″ thick.		None, except that the stopper of the filling hole was driven in.
2	78′	"	Like the case described above fitted with the Silvertown circuit closer.	.39	Sides deformed along the upper edge. Top partly sundered, bottom unaltered.
3	97.4′	"	" "	"	Sides slightly deformed. The convex top was slightly indented at one place. Bot-

CLASS D.

EIGHTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST 27, 1875.

Description of the various kinds of cases around the Countermine.

Description of the Countermine.	Pressure Cases ⅛″ thick, 13.5 High, 9.7 deep. No.	Distance	Affects. k = characteristic.
448.8 lbs. of Dynamite of 75 per cent. of nitro glycerine. In cartridges of 1 and 2 lbs. packed in an iron cylinder with convex ends. ⅛″ thick, 29.1″ high 24.4″ diameter. With an igniting charge of .2 lb. with 2 fuzes of 23 grains of fulminate each. 29.2′ deep in 39′ of water.	1	48.7′	Bursted and lost.
	2	58.4′	Top indented. Bottom knocked in. Sides slightly deformed. The effects were abnormal and different from all other experiments.
	3	68′	Deformed most on one side. Top indented 2.14″ Bottom indented 1.56″ and partly severed. Height = 12.9″ k = 65.
	4	78′	Sides deformed and flattened a little. Top indented 1.56″ and cracked. Bottom knocked out. Height = 12.8″ k = 75.

Pressure Gauges.

Kind and Number.	Dist.	Depth.	Effects Indicated.
	Swedish.		Atmospheres.
5	48.7′	9.7′	18
1	"	29.2′	18
2	"	"	25
8	58.4′	9.7′	9.25
3	"	29.2′	25
4	"	"	28.5
7	78′	9.7′	8.25
6	"	29.2′	16.5
9	"	"	(25.5)
	French.		Compression.
4	48.7′	9.7′	11 mm. = .43″
2	"	29.2	18.5 " = .73″
6	58.4′	9.7	11.5 " = .45″
3	"	29.2	19 " = .75″
5	78′	9.7	3.75 = .14″
1	"	29.2	(36 ") = 1.42″

Different kinds and shapes of mine cases.

No.	Distance	Depth.	Description.	Charge of sand.	Effects.
1	146′	9.7′ in 39′ of wat'r	Steel cylinder 3-16″ thick with convex ends, fitted for 164.4 lbs. charge and Silvertown Circuit closer like those used in the three previous experiments.	164.4 lbs. of sand and saw-dust.	Case uninjured but the shock of the explosion ignited the fuze.
2	175.5	29.2′ in 39′ of wat'r	Steel cylinder ¼″ thick with convex ends, having an inner steel case 1-16″ thick for a charge of 654.4 lbs of powder. Like those used in the three previous experiments.	654.4 lbs. of sand and saw-dust.	Uninjured.

No.	Distance	D'pth	Experimental shapes.	Effects.
1	48.7′	9.7′	Steel sphere ⅛″ thick.	The upper half of the case was indented in three places, of which one terminated in a star shaped breach.

Remarks.

The effects of the explosion of this mine were very irregular since some of the pressure cases and pressure gauges indicated relatively greater effects at greater distances, being in this respect quite different from the other experiments.

This finishes the account of the experiment. In the official report of the Scandinavian Board, the results of these experiments are discussed at length; from which, I will simply give the most important facts under head of explosives and their ignition; the effects of mines; materials, construction and application of mines.

EXPLOSIVES AND THEIR IGNITION.

Gunpowder, dynamite, and compressed gun cotton may be used in submarine mines; musket or cannon powder may also be used, but it should be of recent make. The powder used in these experiments had a density of 1.6 to 1.88 and a gravimetric density of .90 to .94, the weight of one cubic foot being equal to 5.75 lbs.

Charges up to 1000 lbs. will be satisfactorily ignited by a single fuze at the centre of the charge; but to insure the ignition of the entire charge a fuze is recommended, consisting of a glass or zinc tube containing 1500 to 2000 grains of musket powder and two electric igniters at the center of the charge. Two fuzes are recommended for charges exceeding 1000 lbs., and three for more than 2000 lbs., each one being arranged to ignite an equal portion of the charge.

The Board made use of normal dynamite with from 72 to 75 per cent. nitro-glycerine and 25 to 28 per cent. of Kieselguhr. The explosive force is expressed by the breaching of a ½″ plate of the best Lowmoor iron by 2623 to 3086 grains unconfined. It may be used in one pound cartridges or as loosely mixed dynamite; the latter has about the same density as gunpowder. 50.5 lbs. of dynamite in one pound packages has a volume of one cubic foot. Cartridges in very thin paper cases weigh 87 lbs. to the cubic foot when not frozen. The ignition is independent of the size of the charge, but the most convenient method is by a detonator of about 23 grains of fulminate of mercury in contact with the dynamite; an electric igniter with two detonating cartridges may be advisable with large charges.

The gun cotton was furnished by Professor Abel in compressed cylindrical discs weighing .596 lbs. each with a density of 1.1. One cubic foot weighs 56.64 lbs. If moistened with 20 or 30 per cent. of water, gun cotton is not at all dangerous and must be exploded by the detonation of an igniting charge of dry gun cotton, the latter being ignited by one or two fuzes of 23 grains of fulminate of mercury. This igniting charge should be 1.1 lb. for a charge of 220 lbs and 2.2 lbs. for larger charges. The guncotton must be wet with fresh water;

if it is exposed to the action of salt water for a very long time it must be dried again before it can be exploded.

[This statement is not made by any other authority.] The explosive force is practically equal to that of normal dynamite and the relative force to that of gunpowder is for gunpowder as 1—as 1 : 3 or 4, if sufficiently confined.

The Effects of Mines.

The experiments have demonstrated the practical accuracy of the equation $L = MR^3$ and $R = K\sqrt[3]{L}$ when $\sqrt[3]{M} = \frac{1}{K}$ or $K = \sqrt[3]{\frac{1}{M}}$

The values of M and K were determined in the theoretical deductions and proven by the experiments $M = \frac{1}{48.6}$ and $K = 3.65$ for gunpowder, and $M = \frac{1}{160}$ and $K = 5.43$ for dynamite which substituted give these two general rules,

$L = \frac{R^3}{48.7}$ and $R = 3.65\sqrt[3]{L}$ for gunpowder

and $L = \frac{R^3}{160}$ and $R = 5.43\sqrt[3]{L}$ for dynamite,

from which we can deduce the charge, or R, for buoyant mines. If a ground mine rests on a rocky bottom, R will be one third greater in the line of least resistance, but only one tenth greater if the bottom is soft or muddy. If the mine is loaded with dynamite or guncotton the bottom will have no effect.

The minimum depth at which this equation holds true for gunpowder mines is when $d = 0.6R$; and R has its greatest value when $\frac{d}{R} = .65$ to $.71$, or when at the normal depth. The minimum depth for dynamite mines is 0.5R.

The maximum depth is equal to R for dynamite mines, and for ground mines of gunpowder; and to .9R for buoyant gunpowder mines if any lateral effect whatever is desired. The bottom of a vessel drawing 16′ of water—this being taken as the lightest draught of a vessel built like the ironclad Hercules—will be at least 16′ within R when directly over the mine, and this is sufficiently near to effect a complete breach.

The Board make a number of deductions from a series of experiments collected from different countries besides their own, from which

the resistance of wooden ships, gunboats, et cet., is found to be equal to from 1.3 metres to 1.7 metres; or for wooden ships generally, m = 6.56′. We find from these that the resistance of a ship like the Hercules is equal to 13.12′, since it was breached when this distance within the radii of explosion and was not breached when further off. In the same way, the resistance of the outer bottom was found to be equal to 9.84′; so that if we denote the breaching radius by B and the radius of explosion by R as usual, we have the following expressions for the distances at which different kinds of ships may be breached. Wooden or thin iron ships (single bottom) B = R — 6.56′. Stronger iron ships (single bottom) B = R — 9.84′. Heavy double bottom ironclads like the Hercules B = R — 13.12′.

It is also necessary to know the relative position of the mine to the part of the ship to be breached. Theoretical consideration and direct experience demonstrate that a ship will be breached only when exposed to the direct effects; that is, when in the sphere of the funnel. This funnel may be considered as a cone with its base at the surface, and with an angle = (2α,) at the vertex. The value of this angle can only be given by experience, and this angle will determine the horizontal distance of the lateral effect. If the crater were a sphere, the angle 2α could be readily determined by $\cos \alpha = \frac{d}{R}$; but this is only the case when d is the normal depth, and this must be taken as the maximum value of the angle 2α. The results of the collected experiments give the following values for half the angle at the vertex; For buoyant gunpowder mines.

At the depth of normal mines $\alpha = 45°$; when $d = .71$R.

At the depth of overcharged mines $\alpha = 53°$; at the minimum depth, = .6R.

At the depth of undercharged mines $\alpha = 23°$; when $d = .9$R.

For ground mines of gunpowder,

At the depth of a normal mine $\alpha = 40°$; when $d = .71$R.

At the depth of an overcharged mine $\alpha = 45°$; when $d = .6$R.

At the depth of an undercharged mine $\alpha = 25°$; when $d = .9$R.

or $\alpha = 23°$; when $d =$ R.

For dynamite or guncotton mines.

When buoyant or ground $\alpha = 45°$; when $d = .7$R.

When buoyant $\alpha = 60°$; d = minimum = .5R.

When ground α = .55 to 60°; d = minimum = .5R.

At the maximum depth $\alpha = 20°$; when $d =$ R.

THE HORIZONTAL DISTANCE OF THE MINE'S LATERAL EFFECT.

This is the same as the funnel radius previously mentioned and it depends upon the value of the angle α. In fig. 7 let VL be the surface of the water. M = a mine at the depth M A = d.

A M C = half vertical section of the cone of explosion, A M C = α = half the angle at the vertex. MC = R = the radius of explosion $\cos. \alpha = \frac{M\,A}{M\,C} = \frac{d}{R}$. A C = r = the funnel radius at the surface of the water.

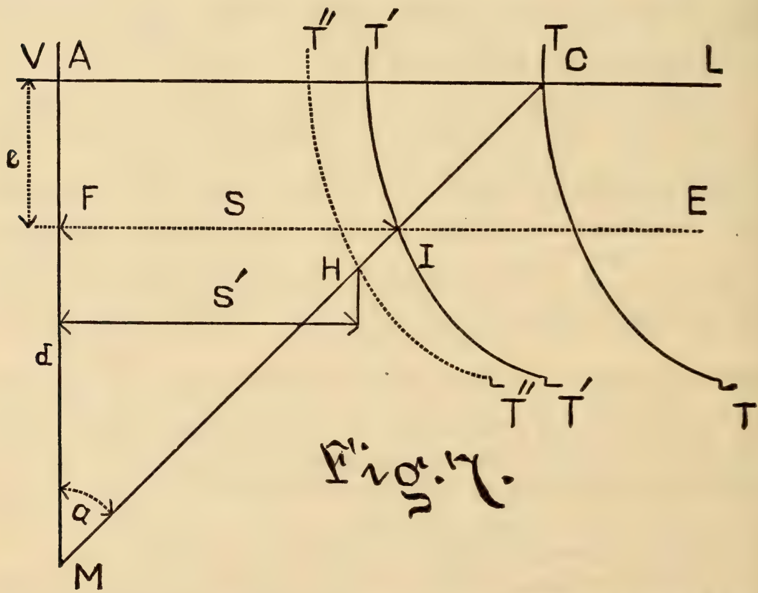


Fig. 7.

The least depth at which the explosion should strike a ship is e or 9'.84 for the heaviest ironclads. If a ship's hull T T of m resistance reaches the point C it will enter the sphere of effect and will be breached when it reaches the point I, if M I $\leqq$ B, the breaching radius. If MI $>$ B and B = M H the hull will not be breached until it reaches the point H or takes the position T'' H T''. In the first case M I $\leqq$ B, the horizontal distance of the lateral effect, or S, will be determined by the line F I = S = $(d - e)$ tan. α; in the other case M H = B by S' = B sine α. If M I = B, then S = S'.

Nine graphical illustrations are given to illustrate the relation of

the depth to charges of from 300 to 1000 kilogrammes of gunpowder and from 100 to 500 kilogrammes of dynamite. From these they find no essential difference in the extent of the lateral effect between mines at the minimum and normal depths, so that the last depth should be generally preferred.

A given charge of gunpowder has its greatest lateral effect at small depths, when buoyant.

If great lateral effect is desired, as with observation mines, it will generally be advisable to use gunpowder charges in buoyant mines; with dynamite, buoyant or ground mines may be used with equal effect.

The size of the charges in service may be determined by aid of the given rules when not indicated by experiment. Contact mines with 9′ or 10′ immersion should have a charge of 22 lbs. of dynamite in order to breach completely a vessel with a bottom like the Hercules, if in absolute contact or within 1′ or 2′ of the bottom; but since absolute contact cannot be always obtained, they recommend 33 lbs. of dynamite or 110 lbs. of gunpowder which when exploded will make a complete breach even when 3′ or 4′ from the ship. This charge will then cause such serious damage to an enemy's ship that she will only be saved from sinking by a most thorough system of water-tight bulkheads, and even then she will most likely be obliged to withdraw from action as disabled. This charge is therefore recommended for all offensive mines.

The charge for large contact mines 10′ to 13′ deep should be large enough to sink an enemy's ship inevitably; but this explosion should not be so great as to affect neighboring mines in a system. In view of this the Board recommends charges of 110 lbs. of dynamite for these mines, which will have sufficient confinement at depths of from .4 R to .5 R. This charge is equivalent to 363 lbs. of gunpowder which would be very much overcharged for this depth, and therefore a considerable amount of force would be lost, and the ship might not be destroyed. If we use gunpowder the charge should not exceed 220 lbs., and the depth should be at least 13′.1, since $\frac{d}{R} = .6$. We can place gunpowder mines closer together in a system of defence than dynamite mines, though the enemy can destroy gunpowder mines with less danger.

To avoid large charges the depth should not be greater than necessary. If we have a choice, the depth should be such that the largest ships may pass over them without touching and this is assumed to be

28.5′ for most cases. The smallest charges are those deduced from .9 R = 28.5′ for buoyant gunpowder mines and R = 28′.5 for ground gunpowder mines and dynamite or guncotton mines. Substituting these values of R in the general equation $L = M R^3$, we have for buoyant gunpowder mines:

$$.9\ R = 28.5', \text{ or } R = 31.7' \therefore L = \frac{1}{48.6} \times 31.7^3 = 655.42 \text{ lbs.};$$

for ground mines:

$$R = 28.5' \therefore L = \frac{1}{48.6} \times 28.5^3 = 440.1 \text{ lbs.};$$

for dynamite mines:

$$R = 28.5' \therefore L = \frac{1}{5.43^3} \times 28.5^3 = 149.66 \text{ lbs.}$$

These charges give very small lateral effects as determined by S = (=R—m) sine α; so that for m = 13.1′, we have respectively; for the above charges and depths,

$$S = (31.7'—13.1') \text{ sine } 23° = 18.6 \times 0.39 = 7.15'.$$
$$S = (28.5'—13.1') \text{ sine } 25° = 15.4 \times .423 = 6.51'.$$
$$S = (28.5'—13.1') \text{ sine } 20° = 15.4 \times .324 = 4.989'.$$

If there is any current allowance will have to be made for a probable change of position and errors of observation, which should equal one half the ship's beam.

The greatest charge that may be used is determined by 0.6 R = 28.5′ for buoyant gunpowder mines and 0.5 R = 28.5′ for dynamite or guncotton mines. Substituting the values of R thus deduced in $L = MR^3$ we have $.6\ R = 28.5'$; $R = 47.5'$; $L = \frac{\overline{47.5'}^3}{48.6} = 2204$ lbs. and

$$L = .5\ R = 28.5';\ R = 57;\ L = \left[\frac{57}{5.43}\right]^3 = 1157 \text{ lbs.}$$

The lateral effect of these charges can be found from S = (d—e) tan α:—if we put e = 9.84′, we have S = (28.5—9.84) tan α =18.66 × tan 53° = 2.49′, for gunpowder mines, and S = (28.5′—9.84′) tan 60° = 32.5′, for dynamite mines.

In order to ascertain how many observation mines will be necessary to defend a channel, we must first find the area of destructive effect of a single mine at the surface of the water; this is found by increasing the above lateral effect by one half a ship's beam (measured at the depth e below the water line), and this may be taken as the radius of the circle of destructive effect.

The size of charges, the kind of explosive, and mutual distances of mines and lines of mines in any defensive system, will depend very much on local circumstances, such as the depth and width of the channel, and the rôle mines are expected to play. Large charges of dynamite require more space for the indirect effects than smaller charges, and two mines with small charges are often more convenient than one large mine. For example, two charges of 660 lbs. of gunpowder each, at the maximum depth and 52′ apart will command a channel of a width of 105′ with an allowance of 40′ for a ship's beam, if both are exploded simultaneously; which is equal to that obtained from 1160 lbs. of dynamite, or guncotton in a single mine.

The Indirect Effect.

The experiments with the pressure cases and pressure gauges were not so regular in the resultant indications as to enable the Board to give any positively accurate expression for the law of the indirect effects. The Board considered Moisson's theory in the light of these experiments in order to approximate a general law.

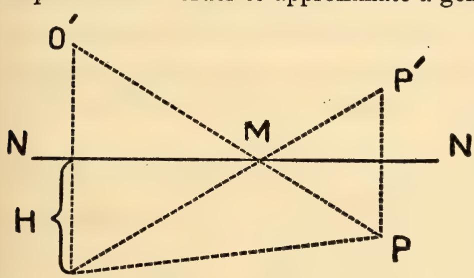


Fig. 8.

In this figure, N N = the water line, O = the centre of a charge at a depth = H, and P = a distant point in the water.

Now a wave of condensation starts from O at the instant of explosion and spreads in all directions with the velocity of sound, 1400 metres per second; as this reaches the surface, waves of rarefaction will proceed from the several points of the surface and spread through the mass with the same velocity, and the instant the point P receives both waves the effect will be nullified at that point.

Now the shortest path to P after reaching the surface will be O M P = O′ P, and the first wave of rarefaction will reach P in the time $t = \frac{O' P}{V}$; the first wave of condensation reaches P in $t' = \frac{O P}{V}$; therefore the effect is operative during $t - t' = \frac{O'P - OP.}{V}$

We may consider the work developed in each instant during an explosion as constant, and that the relative value of $t-t'$ for the different points indicates a ratio between those points and the work developed. If $t-t'$ is greater than or equal to the entire duration of the explosive action, θ, the point P will receive the entire effect. If $t-t'$ is less than θ, P will only receive a portion of the effects, and at all points where the difference between O′ P and O P is equal there will be an equal effect produced. A projection of these would be a hyperbola whose foci are O and O′, N N is the axis of x and O O′ the axis of y. If we put $(t-t') = K$, the equation for the hyperbola gives $\frac{y^2}{K^2} - \frac{x^2}{4\,H^2\,K^2} = \frac{1}{4}$;

but $K = O'P - OP$. $\overline{O'P}^2 = (H + Y) + x^2$ and $\overline{OP}^2 = \overline{(H - y)}^2 + x^2$

$$\therefore\ K = \sqrt{(H+y)^2 + x^2} - \sqrt{(H-y)^2 + x^2}$$

If $H = y$, the point P will be at the same depth as the mine, and this equation reduces to $K = \sqrt{4\,H^2 + x^2} - x$. Now, comparing the results of several experiments when the mines and the pressure gauges were at the same depth, they find a definite relation between their indications and the amount of effect produced at the several points; this divided by $K = \sqrt{4\ H^2 + x^2} - x$ gives a constant quotient. Therefore, notwithstanding the defects of the gauges, the effects may be regarded as constant during the time θ.

If $b =$ the time in which a point at the same depth as the mine is affected, then as before $b = \frac{\sqrt{4\,H^2 + x^2} - x}{V}$, Let $r =$ the effect produced at this point, then $r = \frac{b}{\theta} = \frac{\sqrt{4H^2 + x^2} - x}{V.\,\theta}$;

$$\therefore\ \theta = \frac{\sqrt{4\,H^2 + x^2} - x}{V.\,r}$$

From this we can find θ when r, H and x are known; and if θ is known, then solve by $r = \frac{b}{\theta}$, where b is determined for every point by its position relative to the centre of explosion. The lifting force of an explosion is proportional to the charge L, and the upper surface through which it acts upon the surrounding water is proportional to $L^{2/3}$, and we may therefore regard the time in which the force of the explosion is exhausted as proportional to $L^{1/3}$, from which we have $\theta = K\,L^{1/3}$ The constant K has been determined by the most

accurate experiments as $K = .0028$ for gun cotton, and $K = .012$ for gunpowder, when the weight of the charge is in kilogrammes.

Let $T =$ the work in metre-tons upon a square metre, which, for instance, is that which is sufficient to destroy a mine case at a depth of H and distance $= x$, both in metres; let $\varphi =$ the force in metre-tons developed by the explosive used, and $L =$ the charge in kilogrammes, then $T = \frac{L\,\varphi}{4 - x^2} \cdot \frac{\sqrt{4\,H^2 + x^2} - x}{1400.\,K.\,L^{1/3}}$ by substitution; making $\frac{\varphi}{1400\,K.\,4\,\pi} = U$ and clearing the equation of fractions we obtain

$$Tx^2 = L^{2/3}.\ U.\ \left(\sqrt{4\ H^2 + x^2} - x\right)$$ from which we find

$$x^3 = \frac{4\ H^2.\ L^{2/3}.\ U.}{T\left[\frac{T.x}{L^{2/3}\,U} + 2\right]}$$

Berthelot makes $\varphi = 479$ metre-tons for gun-cotton, which gives $U = 8.75$. At great distances, the fraction in the denominator of the last equation is so small comparatively that it may be neglected, and then, by substituting the value of U, we have $x^3 = \frac{17.5\ H^2\ L^{2/3}}{T}$ or

$$L = \left(\frac{T}{17.5\ H^2}\right)^{\frac{3}{2}} x^{\frac{9}{2}}$$

If we give H and T constant values, this last equation will become $L = A\,x^{\frac{9}{2}} = A\,x^n$ The exponent of $x^{\frac{9}{2}}$ is too great, and does not accord with experience; probably the time in which the explosion is exhausted is less than $L^{1/3}$, at all events the exponent of x must be between 2 and 3. If equal to 2 we should have an effect produced equal to one, though this is only approximately proved by the French experiments. English experiments give the value of the exponent as 3, and these put it at 2.91.

The Board recommends the equation $L = A\,x^n$ for countermines. In this, $L =$ the required charge, $A =$ a coëfficient depending upon the explosive used, and $x =$ the distance at which definite effects are obtained. The exponent n varies between 2 and 3. If the countermines and lines of defence are very deep, use $L = A\,x^2$; if not very deep, use $L = A\,x^3$. In laying out a defensive system, so that neighboring mines may be unaffected by explosions, use the formula

$L = A\ x^2$; and, on the contrary, if to destroy such a system, the charge of countermines should be $= A\ x^3$.

Countermines should be loaded with the most powerful explosives. The maximum charge depends on the means employed for planting them, and the store of explosives brought to the scene of action. In this connection the Board does not consider that charges exceeding 550 lbs. will be used, because of the proportionately large increase in the charge necessary for a small increase in destructive range, and the difficulty in handling large mines when exposed to an enemy's artillery fire. Countermines should be generally used at the undercharged depth, and so remote from the bottom that its irregularities may not interfere with the regularity of the propagated shocks. The Board recommends the depth of from 0.7R to R.

Materials, Construction and Application of Mines.

Cast iron should not be used, because it has not sufficient resistance against countermines without too great weight. The material of the cases must not be too tough, since the case will only be ruptured and not burst.

The Board recommends Bessemer steel plate as the very best material, since it offers great resistance to countermines and is burst into many pieces by the explosion of its own charge, provided the joints are as strong as the plate. Rivets, eyebolts, rings and all projections should be of the best Swedish iron. The thickness depends on the resistance required and the weight that may be permitted. Gunpowder gives its best effects in cases of the minimum thickness depending on the size of the charge, such as 1-16 in. thick for 112.2 lbs. of gunpowder. Air spaces are condemned, and when necessary to give buoyancy should be as small as possible.

Large mines should have proportionally thicker plates; but since the arch or sphere offers the greatest resistance certain shapes may have thinner plates.

The Board recommends the 3-16 inch steel plate case and the $\frac{1}{4}$ in. steel plates case described in the fifth and sixth countermine experiments as suitable for contact and observation mines.

The same material and similar shapes for ground mines with a suitable base for the requisite stability are recommended; $\frac{1}{4}$ inch steel plate is suitable for a ground mine containing 1320 lbs. of explosive. Buoyant cases should have an internal charge case of 1-32 inch to 1-16 inch tinned steel. Ground mines should also have an internal charge chamber to separate the charge from the outer case.

Offensive Torpedoes.

The charge for a spar torpedo should be 110 lbs. of gunpowder, immersed 9.84′, and distant 26′ from the supporting vessel. The boat spar torpedo should have a charge of dynamite or gun-cotton of about 33 lbs., and not less than 22 lbs. The largest charge may be exploded from wooden torpedo boats with an immersion of 9′.1 and 1.4 R = 24′ from the stem of the boat or 22.2′ horizontally distant. The smallest charge may be safely exploded when 19.3′ horizontally distant with the same immersion. With iron torpedo boats it is advisable to increase the distance from the mine to 1.5 R=25.5′.

The Harvey torpedo can breach an iron bottom under very favorable circumstances, but there is very little probability that it can be made to strike fair or below the armor, so that it will very rarely be effective even when loaded with dynamite.

The French towing torpedo is superior, since it can be regulated to strike below the armor. Its charge should not be less than 44 lbs. of dynamite, because it may not always be in absolute contact when exploded. It is advisable to hollow out the cylindrical float and pack it with from 220 lbs. to 440 lbs. of gun-cotton when attacking heavily armored ships as this will seriously damage armor up to 12″ thick, even if it should not breach it.

The Whitehead torpedo should be directed to explode below the armor and should have at least 33 lbs. of dynamite in its conical charge chamber.

The report and journal of these experiments are signed by the board of officers representing the three countries; namely, C. H. Arendrup, Captain Danish Engineers; C. Ekermann, Captain Swedish Navy; Johan Koren, Captain Norwegian Navy.

[There is but one point of disagreement between these and our own experiments, and that is in the relative force of gunpowder and dynamite. In these experiments it is considered as 1 : 3 or 4, while it is stated in Professor Hill's *Notes on Explosives*, that dynamite is approximately 6 times as powerful as gunpowder.]

I am indebted to Captain Thomas O. Selfridge in charge of the U. S. Torpedo station for permission to make this extract from my translation and also to Lieut. G. W. Tyler for reading the paper before the Institute.

THE CHAIRMAN: I think you will all agree with me in the opinion that the paper we have just heard read is an exceedingly valuable and interesting one not only to the service at large, but especially to those who have made any study of torpedoes and submarine mines.

The report embraces a large and extended course of practical experiments, methodically arranged, and carefully executed, and the results obtained seem to me to be more complete and satisfactory than have been developed by any previous investigations in this important branch of our professional knowledge.

Whether the ratio of effective explosive force, for different bodies, or the coëfficient of explosion, has been definitely determined may perhaps be a matter for further discussion and experiment.

The conditions of explosion exercise so great an influence upon all explosions and especially upon gun-powder, which is usually taken as a standard or unit of comparison with the more violent explosive compounds, that a perfect agreement in this respect is at present hardly to be expected.

This report appears to be very carefully and thoroughly translated and I think the Institute is much indebted to Lt. Beehler, for placing within reach a paper containing so much practical and useful information, as well as patient research, in connection with a subject which has so direct and vital a bearing upon the conditions of both offensive and defensive modern naval warfare.

NAVAL INSTITUTE ANNAPOLIS, MD.,

April 26, 1881.

Comdr. F. V. Mc Nair, U. S. N., in the chair.

DISCUSSION ON THE PRIZE ESSAY OF 1880.

"The Naval Policy of the United States."

Commo. Simpson: I wish to bear my testimony to the excellence of the paper of Lieut Belknap on what should be our naval policy. I have read the essay with interest, and I recognize very deliberate thought and conservative conclusions. Though I don't approve of all his suggestions, yet I find nothing proposed that is revolutionary or unreasonable. I congratulate the writer on the arrangement of his matter, concluding as he does with a summary of the points on which he has dwelt, thus enabling us to grasp certainly at his meaning.

The treatment of the question as to the necessity for the maintenance of a strong Navy by the United States is admirable, and his reasons are unanswerable, supported as they are by numerous instances, in which it is a matter of history that the influence of the show of naval force vindicated our national dignity, and has proved most efficient in general police. The argument drawn from the present state of affairs about the isthmus of Panama is most apt, for we are likely to see the principle of non-intervention in the affairs of the continent violated unless our government has a suitable force with which to support its protest. In case of a war also, we all can recognize that within ten days after the declaration New York city can be put under a contribution for millions to defray the expenses of an enemy, who happens to be possessed of a few powerful iron-clad vessels.

In the third division of the paper we get at the gist of the matter, in the presentation of the means that the writer would propose in order to revive the Navy, and he very sensibly advances the idea of a Naval Board at the Navy Department to perform the duties of the old Board of Navy Commissioners, although the duties at this time would not be so arduous as formerly, as the Bureaus might be retained to aid the Board. There would thus be a professional and responsible body of advisers for the Secretary of the Navy who, in repeating their advice and recommendations, could speak with no uncertain sound, and could thus remove what Lieut. Belknap alludes to as an insurmountable obstacle at the present time, the difficulty of making an impression on the minds of our legislators that the Navy De-

partment has a system on which it will work consistently; for without being satisfied on this point it is right for them to withhold appropriations which they think are only to be frittered away on vague experiments.

The details of the duty for the Advisory Board seem well indicated, but in practice these would naturally suggest themselves, but I note one point made by the writer which I heartily approve; it is the one that refers to special legislation by Congress in regard to individuals, requiring that no such bills shall be considered by Congress except upon the favorable recommendation of the Advisory Board. Of course this would require in the first place an act of Congress, but I believe it is one that would be readily passed if recommended by the Secretary, as it would relieve Congressmen from a serious source of annoyance.

There is one advantage connected with the Advisory Board that has escaped the notice of Lieut. Belknap, which I will allude to. There is nothing that can be done which will approach nearer to taking the Navy out of politics, and as long as it remains at the mercy of politics, so called, but rather at the mercy of party men, all the recommendations in the world will be of no avail. With the Secretary alone at the Department, making recommendations on his personal responsibility, I don't care how much interested he may be in the Navy, he is still the slave of his party, and he dare not, for his party's sake, recommend appropriations for such expenditures as will expose his party to the charge of squandering the public money. But with a Board behind him, having no interest whatever in politics, not removable by party, he will be freed from the trammels of party, and can fearlessly recommend what he honestly believes will be for the good of the Navy, and for the credit of the country; this, I think, is the most important feature that would arise out of the formation of an Advisory Board.

I do not agree with the writer of the essay in the change that he would make in the system of promotions. I think that we have the best system in the world. When extraordinary instances of skill or gallantry occur Congress will always reserve to itself the right to treat them on their merits, meanwhile there is no system so uniformly just as promotion by seniority. During the late administration of the Navy Department the Navy received a shock which alarmed it and which should have the effect of closing more than ever the door to personal favoritism and political pressure.

I disagree with the proposition to dispense with Boatswains, Carpenters, and Sailmakers. The last two can be dispensed with in small vessels, but there are times when their services are all invaluable, and, besides, these positions offer high incentives to the boys that we are trying to train up for seamen in the Navy, and the goal of their aspirations should not be taken away from them.

I agree with Lieut. Belknap in his opinion as to reducing the number of our Navy Yards, as by concentrating the same effort as now we can get better results. I agree with him as to retaining Norfork, Pensacola, and Mare Island, and I would also retain a small station at Portsmouth, New Hampshire, but I would gradually abandon Boston, New York, and

League Island, and I would recommend the establishment on the Thames River, at New London, of what should be the large naval arsenal of the country, removing to it the machinery and tools now at New York, Boston, and League Island, and adding thereto such additional improvements as would be required for a first class yard fit for a nation of fifty millions of people. It would be out of place for me to dwell on this matter, but I agree with Lt, Belknap that at present our expenditures for navy yards are spread out over too much surface.

Lieut. R. P. RODGERS: The plan of the system of promotion proposed by Lt. Belknap seems to me one of the most striking points of his Naval Policy which I have read with much interest. Although it has many features which should recommend it yet I doubt whether it would be acceptably received by the service at large. It is practically the French system, by which an officer is sure to get his promotion by seniority, and may secure it earlier by distinguished merit or by some signal act of service. Whether such a system, generally applied, in our country, would not be abused by means of political influence and patronage is a question to be solved only by experience.

I would, however, advise a plan of a similar but less extensive nature. I would recommend the plan of *selecting* our *flag-officers* from the list of captains. No captain should be eligible for promotion until he had seen a stated term (say two or three years) of sea service as a captain. By this means the best captains would seek commands as soon as they entered the grade, and with the incentive of a possible promotion before them, they would put forth their best exertions to improve their ships, (and thus the service) in every possible manner, in other words they would naturally take greater pride and interest in their work.

The flag-officers *selected* might not always be the best men eligible, but they could certainly be men of some distinction. Promotions to brigadier generals in our army are made in this manner and as yet no man without merit has been advanced. It would probably prove equally good if adopted for the Navy.

If this were done, flag officers would all be men of high intelligence, broad views, and strong character. The head of the Navy would then be strong, and the body would soon feel the influence of its strength.

I believe that this would prove a beneficial change in the system of promotion of our Navy, and I think it is probably the only safe one.

It may be claimed that the commanding officers also should be selected, but by increasing the field for selection there would be more scope for political and other outside influence: and although I think such selection would undoubtedly be beneficial (should it be judiciously made) yet the innovation would be so decided that I do not believe it would be accepted by the service.

P. A. Engnr KAFER: The first and as far as I can see the only step in the future Naval Policy of the United States as set forth in the essay is to re-establish a Board of Navy Commissioners which shall be an Advisory Board to the Secretary of the Navy.

If this Board is to direct the Secretary what to do, or order the Bureaus to do whatever it appears to the Board most expedient to be done making their decision final in all matters connected with the Navy Department then the office of Secretary of the Navy might be abolished as he would be a figure head only; but if the Board is to be under the direction and supervision of the Secretary, being advisory in its action, and only that, I can see no necessity for creating such a Board, giving the Secretary three advisers in addition to the eight provided by law; the Secretary can now get the opinion of any officer from the highest to the lowest if he desires it.

The reason for organizing the Bureau system in the Navy Department, was to fix the responsibility of any act performed under the cognizance of a Bureau, which was found to be impossible under the workings of the Board of Navy Commissioners prior to 1842.

Congress and the Secretary of the Navy were in accord on this point and both deemed it necessary to the interests of the Navy to abolish the Board of Commissioners and substitute the present system, not because there was any objection to the members of the board; as they were appointed as chiefs of bureau by Secretary Upshur, immediately on the bill re-organizing the Navy Department becoming a law; the objection was to the system.

Secretary Upshur in a communication to Congress stated that though the reorganization of the Navy Department under the system recommended would involve an increased expenditure of $19,000 per annum to pay the salaries of these bureau officers, it would, by fixing the responsibilities of such bureau and every act performed under its cognizance, be a saving of $700,000 to $ 800,000; and not only was the Secretary anxious for a change, but Congress also demanded a change in the administration of affairs in the Navy Department.

And now it is proposed after an experience of nearly forty years with the bureau system to go back to a system that was unsuitable to the wants and requirements of the Navy, when they were much simpler than they are to-day.

The author of the essay says that, "there was no call for the abolition of the Board," but from the records of the debates in congress and the communications of the Secretary of the Navy at that time, it will be seen that there was a decided call for the abolition of that Board, and the wisdom of the change was not questioned at that time.

Will we get officers as members of this proposed Board that are in any way superior to those selected as chiefs of bureaus? I think not.

The supposition is that we get the best man for chief of bureau, and we would take this same man as a member of this proposed Board, and the next best man for chief of bureau.

In reference to the question of the establishment of such a board as proposed in the essay, I will quote from a letter of a Chief of Bureau on this subject.

"I can conceive of no possible object in this. The present bureaus constitute an admiralty board with all its advantages and without its defects. The only modification I would suggest would be to require, by

law, a daily meeting for conference presided over by the Secretary of the Navy or senior Chief of Bureau present, the minutes of the proceedings to be taken down for future reference.

If a separate admiralty board was constituted and the bureaus retained it is probable that the same reasons that created me Chief of Bureau would put me on that board, and some inferior man put in as Chief of * * * ; and so with all the other chiefs, which would do nothing to conduce to harmony of action.

The reunion of chiefs proposed with their language taken down would prevent its assuming the character of a debating club, and each man become responsible for the advice he gave the Secretary; his views, if erroneous, being combated on the spot by the other chiefs."

The late Commodore F. A. Parker says, when writing on this subject:—"Much has been said of our defective system of naval administration; but when we remember that under that system a force was organized in 1861 that effectually blockaded our sea-coast from Virginia to Texas, a Herculean task which Europe pronounced impossible; and a number of monitors put afloat in 1862, which excited the admiration of the world; and further when we recall the triumph of American over English ideas in the memorable conflict off Cherbourg, of June 19, 1864, I do uot think we need cross the ocean for instruction."

And with the opinions—as here expressed—of these eminent officers of the Navy I fully agree.

The Naval Policy of the United States has been much discussed by officers of the Navy, and these discussions have left the impression on my mind, that the naval policy as well as the policy of the naval officer, is to induce Congress to appropriate money enough to build ships that will compare favorably with those of England and France in numbers as well as in kind;—but the naval policy as set forth in the essay is, the re-establishment of a Board which was acknowledged on all sides to be a failure forty years ago; and if this is to be the future policy of the Navy, I think we are much better off without a policy.

It has been said that Congress would furnish the money to build ships if the Navy Department would furnish the designs for them.

On the contrary I believe that there are designs for vessels with all the details of construction now ready and only awaiting an appropriation from Congress to build the ships.

The monitors now on the stocks should be completed, and would make very efficient war vessels of their class;—though by no means such vessels as might be designed to-day.

As the author of the essay, says "after all it is Congress that decides the Naval Policy of the country."

If Congress should agree with the author of the essay, and authorize a Board, organized as proposed, the members being specialists in their own profession; that of ordnance, seamanship and navigation,—these subjects they would be fully competent to judge, and their opinion on them would be of more weight than the opinion of any one who had not made these

subjects a study and followed them as a profession; but in fixing on the best type of ship or to get a ship that will fulfil the conditions required of her, as to speed, ability to maintain that speed for a given time, strength and weight of the structure, stability and many other details, a special knowledge of the profession of engineering, and naval architecture, practical and theoretical, is necessary.

The engineer and naval architect are better fitted, than a navigator, seaman or ordnance officer, by their special professions, to form an intelligent opinion on the subjects of engineering and naval architecture.

The bureaus, that must work in accord to make a successful vessel of war, are Ordnance, Engineering and Construction, and as I have already said, must be men competent to judge of all the details of a ship; and these men we now have as the chiefs of bureau.

If specialists are not best fitted to judge of subjects pertaining to their own profession; then if a question of ordnance is to be considered, the Board should be composed of persons having no special knowledge of ordnance, instead of officers that make that subject a professional study, and if the subject to be considered is chemistry, the Board should be composed of persons who are not chemists.

But it is well known that when any person or organization wish an opinion on any subject, they seek that opinion of those who have made that subject a study, and for this reason I consider that such a Board should be composed of all the chiefs of bureaus instead of three men who may be very eminent in their own profession, and fully competent to judge of any question pertaining thereto, but not as competent to give an opinion on matters pertaining to other professions.

It has been asked what ships have we now, that have been built under the bureau system. I point to the Trenton, ships of the Vandalia and Adams class built since 1870; the Vandalia class have equal if not greater speed than the vessels of the Gem class of the English Navy, vessels of about the same size as the Vandalia; the frames of the Gem class, being of iron, they are superior in that respect; the height of the boilers of the Vandalia class being about two feet less than those of the Gem class and with the same draught of water, places the boilers of our own vessels, two feet more below the water line, giving them greater security and protection from shot.

These vessels, I consider good vessels of their class, and a very desirable class. Much has been said of the worthlessness of the vessels built between 1861 and '65; but they were good vessels; they served their purpose, fulfilling all the demands required of them; it is true that they are rotten, but it was known at the time they were built that they would not last, they were built chiefly of white oak, the best timber that we had; but had the frames been made of iron,—as they might have been—instead of wood, we would have a number of good cruising ships to-day.

It was due to the conservative influence in the Navy that they were built entirely of wood; but since then we have made some progress and I hope to see still more in the right direction, instead of going back to the ways of forty years ago.

Comdr. Cooke: I have read with great interest Lieut. Belknap's prize essay on the Naval Policy of the United States. He has certainly drawn a very truthful yet unflattering picture of the condition of our Navy. Indeed were its efficiency at the moment alone to be considered, it might with accuracy be ranked after that of Holland, and perhaps after those of Brazil and Japan.

We have not a single armored sea-going ship, and can hardly be said to have any modern cruising vessels, and no armaments of modern rifled guns; yet a brief glance at the very complete and excellent annual reports from the Navy Department is sufficient to set forth how earnestly the naval authorities have begged and implored Congress, from year to year to provide the necessary funds for keeping abreast with the times.

Besides being the right arm of our national defense, our navy is, of course, an important and necessary ally of our commerce, and their development must be mutual. The point to which its efficiency should be carried must, therefore, depend, in a great measure, upon the amount of commerce we have to protect.

Our Navy may be sufficient now to protect our commerce, in the present stage of its development, for we can hardly be said to have either Navy or commerce worthy of consideration. But as our surplus productions are annually increasing and must be transported to foreign markets or become a total loss in our own hands. the question whether or not the Navy shall be improved so as to provide for this state of anticipated development must quickly be decided. And it is well to remember, that if the freights paid by our people to vessels sailing under foreign flags had been retained at home and allowed to become part of our national wealth, our ability to meet and overcome the embarrassments of trade would have been greatly increased. It is very clear that we cannot afford to continue our dependence upon foreign nations for the transportation of our surplus products to the markets of the world. The benefits and profits of our own carrying trade belong to our own people and should be enjoyed by them.

We are certainly the great "middle kingdom" and have the most favorably located business stand on the face of the globe. From our geographical position and territorial advantages we may justly aspire to commercial supremacy, which if we fail to achieve we cannot expect to maintain a position in the front rank of nations.

From the whole of our vast country comes one universal wish for a restored American marine. We are great in production, great in internal commerce, and the whole country is now looking with anxious hopes for the building up of our shipping interest and of making it our principal arm of defense in war and our proudest boast in peace. Why should we not hope for a glorious future for our marine if we will only devote our enterprise and intelligence to this important interest, so long prosperous in the past.

Under our present policy and laws we cannot successfully compete with foreign countries in our ocean carrying trade, and the remedy must be to relieve our shipping employed in foreign trade, from all restrictions and

burdens which place it at a disadvantage in competing with foreign vessels. This must be accomplished in the near future, and all admit that our marine resources must be restored or we shall be disarmed of our defence, and our productions will be at the mercy of the nation which possesses itself of the means of carrying them. Should we not, then, at once begin to remove abuses, to introduce improvements, and to build up our long neglected marine?

We have stood with folded hands and permitted our rivals in naval power to get far in advance in a line of improvements in which the United States not many years ago knew no superior.

The first step in the future naval policy of this country, as recommended in the essay before us, might be taken at once, by order of the Secretary of the Navy, and would be a great stride in the right direction. It being the establishment of a Board of Naval officers, which should determine certain vital points, therein briefly summarized.

The recommendation to modify the present system of promotion by seniority, by occasional selection, would not accomplish the desired result, as those most influential and not those most deserving would gain by it. To encourage retirement would be far better.

It is useless to attempt to enlarge upon the points suggested in the prize essay under consideration, but I am sure you will agree with me that it is full of excellent ideas which we should earnestly advocate in the hope that our naval policy may be fixed and its development commence at the earliest possible moment.

Lieut. BELKNAP. If the appointments to the position of warrant officer could be made solely upon the recommendation of naval officers through the Advisory Board, the grades would doubtless be useful as incentives to the naval apprentices, as suggested by Commo. Simpson. But would not the end be as effectually gained by making the chief petty officers permanent positions dependent upon good behavior, and would it not be an incentive equally stimulating to the apprentice to know that by length of service, good conduct and ability, he would inevitably fall heir to one of these ratings independently of the political influence his friends might have? With the exception of gunner, the usefulness of these grades passed away with the sailing frigates, and I trust Commo. Simpson will pardon me for saying that I see no reason why we should continue to swell the total number of officers in the service by some one hundred and seventy-five (active and retired) and to deprive our already too crowded berth decks of the space that might be gained, for the sake of affording an incentive to the naval apprentice.

The plan for the promotion of flag officers as suggested by Lieut. Rodgers is rather more of a sweeping change from the system now followed than mine, for it would certainly be a greater innovation to choose all of the flag officers by selection instead of every third one, and with how much more force would the objection on the score of political influence apply in the former case than in the latter. But with an Advisory Board to choose the officers to be promoted why stop the selection at flag officers? As Commo.

Simpson so ably says, nothing could be done which would approach nearer to taking the Navy out of politics than the establishment of an Advisory Board, and that being the case we might feel confident that the recommendations of the fitness of an officer for promotion over the heads of his seniors in length of service would be free from political influence or party bias. Congress has the power to advance an officer a grade, but only for war services, or for extraordinary heroism; my plan provides for peace, to prevent minds rusting during the long years that must elapse before promotion. Take for instance the graduates from this School. We all know that each year some manage to get through by hook or crook who should not. Should not the bright men of the succeeding class be given an incentive to perfect themselves in their profession and what more fitting one than that they should step over the heads of the laggards in the class above?

To Congress it is that we look for our very existence; it is to Congress then that we should naturally look for a naval policy. But without a policy we can so prepare ourselves that when one is adopted we shall be ready to take advantage of it. This can best be done, in my opinion, by the establishment of an Advisory Board. The needs of the service will then be defined, and the unification of its management being completed, steps can be taken to place the Navy in a condition worthy of a nation of fifty millions of inhabitants.

Undoubtedly the Secretary of the Navy can get opinions from the different chiefs of bureaus, but do they agree? Is it not necessary for the Secretary after they are received to endeavor to form the diverging, and, but too likely, directly opposite opinions into a settled plan? That this can be done and that a master mind can wrest success from such unpromising sources is evident from the management of the Navy Department during the late war. But similar circumstances would have to recur to permit any one man taking the responsibility and sole direction of affairs as Mr. Welles did. In time of peace few men not trained in the service would venture to act on the plan of one specialist as opposed to that of another, both being chiefs of bureaus.

But with a wise and competent Advisory Board to advise and encourage, as Commo. Simpson shows, the Secretary would be able to guide with no uncertain hand the branch of public service committed to his charge. The growing wants of the Navy in 1842 demanded the establishment of the Bureaus, for it was too much to expect that three men could give the care to the details for which seven are now necessary. But in the itching for change the Advisory Board fell. I think, and I am not alone in this opinion, that it would have been far wiser to have increased its efficiency by establishing the bureaus, subordinate to an extent, but charged with special duties, leaving general affairs to the Board. In proof I say look at the state of affairs to-day:—seven heads, often working against one another, often with entirely different plans for ships—interior arrangements, discipline, et cet. The responsibility of some things may be fixed, but who is responsible that we have no Navy worthy our nation? Is it not on account of the lack of unity shown? Does it not to a great extent arise

from the desire of each Bureau to be left alone and to claim non-interference on the score of non-interference?

The fault was not in the old system; that worked admirably. The three commissioners needed executors to carry out the details after a general plan had been decided upon. We cannot say that better men can be found for the Advisory Board than we have for chiefs of bureaus. Were not the same men who were commissioners made chiefs of bureaus? The Advisory Board would not build the ships, nor put the engines in, nor yet the guns: but after deciding upon the class or type of ship required to carry the gun selected, it would say to the constructor, build the ship; to the engineer, design and construct the engines. The men who go to sea in ships, who command them and who have to fight them, might then have some regard paid to their ideas. As it is the constructors build and say to the engineers and ordnance officers, put in your engine and guns as best you may.

I have listened with great interest to the criticisms passed this evening upon my essay and while it is but natural that differences of opinion should exist as to the remedy, I think that all who have spoken can hardly but recognize the fact that we have no naval policy, that we go on year after year in a hap-hazard way trusting to luck, and that it is only when a strong and prevailing sentiment exists that any decided step is taken. I believe further that most of us must feel that the future is unsettled, not to say dark; that the Navy may at any moment after a futile resistance be swept from existence on the seas. And I ask you, is it not time that we, representing different branches of that Navy, should, sinking minor differences, join together to bring about a change that in case of our Country's need would give us an opportunity of supporting its cause with some show of success? Can we afford to go on, with no settled plan, with conflicting aims, until war opens our eyes to the necessity of our unification? I believe that men can be found among us, who, appointed to the Advisory Board, could be just to all, partial to none. They need not be specialists who are generally men of bias, but they should be men of sound judgment, clear views, and impartial minds. I have sufficient trust in human nature to believe that such men can be chosen, and their voice, speaking for the Navy, would lift us from the slough into which we have fallen and restore us to the position we should occupy among the navies of the world.

NAVAL INSTITUTE, ANNAPOLIS, MD.,

JUNE 8, 1881.

REAR-ADMIRAL C. R. P. RODGERS, U. S. N., in the Chair.

A PROPOSED ARMAMENT FOR THE NAVY.

BY COMMO. E. SIMPSON, U. S. N.

My object in addressing the Institute is to ask its attention to the consideration of the important subject of the ordnance of the Navy, and to suggest some ideas which may assist to lead to general agreement upon this great "want of the Navy." We all agree on one point in reference to this matter, which is that we are deficient, that we are behind the times, and that it is absolutely indispensable that we must make a determined and vigorous effort before we can hope to resume our old position among the nations of the world, but while we agree on this point, and while each is ready to suggest some remedy, we have concluded upon no fixed line of action, and our confused and sometimes contradictory suggestions can have no effect on the government in inducing a supply of the necessary means to accomplish our purpose, for Congress naturally hesitates to appropriate money for a purpose on which it sees that the experts on whose judgment it must rely for guidance in legislation, are themselves divided in opinion. My object, then, is to submit to this body of experts the result of my matured reflections on this subject, giving my reasons for the faith that is in me.

Before proceeding to legislate for the present and the future it is the course of true wisdom to review the past, and to gather from such retrospection such rules for guidance on the general subject as may be useful in directing us aright, for there are certain fundamental principles involved in this matter which must not be discarded nor be allowed to lose their controlling influence in the excitement caused by embarking in new ideas; the furor attending the embracing of a novelty

must not make us desert first principles,—this is true wisdom. There is no doubt that in the past the Navy of the United States has been most happy and successful in the possession of ordnance of especial excellence. There is no department of our public service that has been more fortunate in the selections that have been made of officers to direct it than that of our naval ordnance; the names of Warrington, Morris, Harwood, Ingraham, and others, show to us the care that has been taken in the selection of men who were fitted for the work, and the name of Dahlgren is known not only to us but to the world as that of the founder of a system which in its time was the type of perfection and the standard of imitation. In the period of change through which artillery has been passing during later years the names of Case and Jeffers are known as suitable successors to the before-mentioned, the latter having brought to the Bureau the results of many years of practical experience and study, and having proved himself, during a very trying time for the reputation of an artillerist, well worthy of the responsible position in which he has been placed. That Commodore Jeffers has not gone farther than he has in the road of development may be due to circumstances not under his control, and we have a right to conclude from his official statements that he is not content with the present condition of our ordnance. In thus bearing testimony in commendation of what has been done, without giving it my unqualified approval, you will recognize that, in any suggestions that I may submit, it is not my intention to animadvert upon the results that we now see nor to criticise harshly the acts of others; I shall but express opinions which I think if adopted will expedite the result that all so earnestly desire. With this preamble, simply to show the spirit in which I approach this subject, I will now proceed to its consideration.

As I remarked before, we must begin at first principles, and we must understand what was the chief cause of our former superiority over the other nations of the world in this matter of ordnance. It could not be a matter of accident, such men as we have mentioned did not trust to luck, nor determine a calibre nor the dimensions of a gun at haphazard. We must see what law controlled them in their designs, and we must see whether, under the new conditions of the subject, we must be bound by it, or whether we are at liberty to depart from it.

With the smooth bored gun, the greater the calibre, the greater was the range, accuracy, and penetration. The well known laws that govern spherical bodies opposed by the resistance experienced in passing through air are well known to you, and exhaustive experiments proved

the proportionate penetration in wood due to calibre. Up to the calibre of XI inches the increased weight of the smooth bored gun was not felt as an inconvenience, for the increased charge of powder and weight of shot added so much to the moment of recoil that the additional weight of the gun assisted to control it. The question is now whether, under the new conditions, it is necessary, in order to secure range, accuracy, and penetration, to adhere to the old rule and to aim at large calibres.

Now I do not propose to deny that even with rifled cannon, the larger the calibre, other things being proportionately increased, we will secure increased range and effect; of accuracy, we may safely assert that it will not be increased by increase of calibre. We ask then if the increased range due to increase of calibre is wanted when, with the smaller calibre, we can obtain all the range that we can possibly avail of within distances really practicable for sea fighting, and we must allow that the range of any rifled cannon of ordinary calibre is all sufficient for all practical purposes. For accuracy and range then we can conclude that in order to secure these qualities we do not require large calibres for rifled cannon. As to penetration and effect I will postpone my direct remarks on the point, leaving my position on it to evolve from the following treatment of the subject.

In considering myself relieved from the trammels of calibre, I take it for granted that I will not be misunderstood as disallowing any of its advantages. I only wish to assert that, under the new circumstances of rifled cannon and elongated projectiles, the conditions are so altered from what they were with smooth bored cannon and spherical projectiles that sufficient energy of shot may be obtained for all practical purposes from guns of moderate calibre, and that by adopting a battery of easy manipulation we may be saved from the necessity of imposing upon guns' crews the labor of handling ordnance material of great weight.

The very important consideration, also, of the character of vessels that we are called upon to arm bears directly on this point. Judging from what we can gather of the majority opinion of the Navy, and of the disposition of Congress, our Navy is to be limited to unarmored cruisers. I mean our cruising, sea-going Navy. Iron-clad monitors, from present appearances, seem destined to embody all of armored vessels that we are to possess, and they are only fitted for harbor defense and for service along the coast in the vicinity of harbors. It is the unarmored cruiser that we are now keeping in mind when planning a system of ordnance for the Navy.

At the outset of this investigation there is one thing that ought to present itself to our minds derived from our own practical experience on board ship, and that is the necessity of avoiding a multiplicity of calibres. There was a time when a practical uniformity in this respect was achieved in the armament of our ships of war, but since the partial introduction of rifled cannon we have wandered sadly away from the lesson that we had so well learned. This has been caused by the process of change being so very gradual, and the tentative style of the introduction of each experimental gun, but if the change from smooth bored to rifled cannon is determined on it ought to be done at once, and there will be the opportunity to re-establish this desired uniformity without loading ourselves with a supply of experimental guns which must disappear from the batteries, and become useless stores, when we adopt a permanent armament. The presence of these mixed batteries makes the practical work of manipulating them very complicated, and makes the process of serving the ammunition an intricate question to solve, as each calibre requires a distinct and separate detail of men to be appointed for its supply. In addition to the smooth bored guns which, as yet, form the chief part of our armaments, almost every ship carries an 8 in. rifle, a 6 in. rifle, and other smaller rifled cannon in battery which have to be supplied with ammunition in action; these, in addition to a small steel rifle which ornaments the poops of our ships of war, and boat guns, and machine guns. This shows the unsettled condition in which this matter rests. Our batteries are all experimental, no conclusion seems to have been arrived at as to what is best to adopt, and the present multiplicity of calibres is the result. In planning an armament for the Navy it is necessary to keep in view this important requirement, and to adopt a calibre well fitted for *general* instead of *special* purposes. There must, no doubt, be some exceptions to this rule, as, in special vessels where machinery is adopted for working the guns, exceptionable calibres will be admissible, but I speak of unarmored cruisers which are to constitute our sea-going Navy, and in which the guns are to be served by man power.

It will be well to mention here a particular phase of the present development of artillery, which, to my mind, *forces* the suppression of all of these small guns that help to make up the mixed batteries of our ships of war, for in view of the development I refer to I can see no practical use to which they can be put. The 6 in. rifle on the top-gallant forecastle, the small steel rifle on the poop and other small pieces are all on an uncovered deck, and before they can be of any use against

an enemy they must be used at close quarters. Now in the advanced condition of machine guns I think it is evident that no guns can be served at close quarters on an uncovered deck. All ships of war are now supplied with the Gatling, or other machine guns, and as soon as contending vessels approach within the range of these pieces the uncovered deck of the adversary will be swept by them. In single decked vessels this exposure cannot be avoided, but in a double decked ship if guns are to be mounted on a spar deck they must be placed so as to be protected by the forecastle and poop decks. In passing, I would say that in order to avoid weight at the extremities of a ship, I would extend the forecastle well aft and the poop deck well forward, in order to afford this protection, but guns so mounted should be of the same calibre as those that form the main battery on the covered deck; and, if "all around" fire is deemed essential, it can be obtained, as in one of the types of iron clads, by introducing the "tumble-in" system of constructing the upper works forward and aft. This arrangement will answer the objection that might be raised to my proposition to suppress the gun on the top gallant forecastle, that by so doing I deprive the ship of her bow chaser; fire ahead will be better provided by this arrangement and the gun will still be serviceable at close quarters. But this is a point rather of construction than of ordnance, but closely associated with it, and affords a good illustration of the intimate connection between the two; I throw out the idea as a practical suggestion and pass on to the consideration of *the* gun which with safety we might adopt for general purposes in the Navy.

It is no new idea to have a *special* gun for the Navy; we have had one for years; the IX inch Dahlgren gun has occupied that place, and we regard it as especially our pride and our defence. It constitutes the main feature in the batteries of all our ships of war, and if we are satisfied that under the new condition of things it is necessary for us to change our batteries, would it not be the path of wisdom to devote our investigations and our experiments to selecting a substitute for the gun which occupies the most useful and important place in our armaments. By selecting a gun to take the place of the one of which we use the greatest number we advance by the shortest route to solve the problem of new armament; consequently, instead of experimenting with guns of which, if we select one, it will only be for use as a pivot gun, of which we use but few, I think it would be wiser to first determine on a gun for broadside batteries, of which we require many.

In opposition to this idea it will not do to say that the whole Navy

is in a state of change, and that, if we at once embark in providing ourselves with a large number of guns for broadside batteries, we may find, after we have them on hand, that the style of our ships may be changed, and so to argue that no decided move should be made in providing full batteries until the character of the ships of our future Navy is determined; this excuse for delay is played out, there is nothing in it, and it has done much harm already in deadening effort and checking invention. The character of our future Navy *is* determined, at least until the time of the next war in which we may be engaged, for it will not be until then that any iron clad sea-going cruisers will float our flag on the sea, and until then we can feel assured that our cruising Navy will consist only of unarmored cruisers of wood, or composite build, of moderate dimensions, for which our present guns would form adequate armament if it were not necessary to provide rifled ordnance so as to put them on an equal footing with similar vessels of other nations. There is no excuse for delay in this matter in consequence of the seeming undetermined character of the ships which are to carry the new guns, and all we have to do is to find some gun of about the same weight as our present IX inch, only of immensely increased power.

The weight of the IX inch Dahlgren gun is 9,000 lbs., and that of the carriage is 1,300 lbs. In order to approximate to the same total weight, and at the same time to secure a gun of greatly increased power we must expect to increase very much the weight of the carriage, for the increased energy of the shot will impart an increased energy to the recoil which must be provided for by the carriage, and we are thus forced to select a gun which will be of less weight than the one that we wish to replace. In looking over the list of modern guns, which have proved to be an undoubted success, I select the 6 inch steel gun of Mr. J. Vavasseur, which seems to me to offer to us a ready means of emerging from our present embarrassment. I will give some of the particulars of this gun.

Weight 3 tons, 17 cwt.
Length, 162 inches.
Diameter of bore, 6 inches.
Length of bore, 150 inches (25 calibres).
Charge of powder, 40 lbs.
Weight of projectile, 80 lbs.
Muzzle velocity, 2,000 ft. per second.
Total energy, 2,219 foot tons.

Penetration in iron at muzzle, 11 inches,
at 500 yards, 9.9 inches,
at 1,000 yards, 8.7 inches.

You are all familiar with the power of the IX inch gun, so it would be supererogatory for me to dwell on it in comparison with the above; and I avoid doing so from the affection that I have for the old piece. I would not wish to seem to belittle it, but it cannot help being a smooth bored gun of cast iron, and we must, with what sentiment you will, quietly and tenderly store it away with our obsolete bows and arrows, in our museums of war material, where we can take the youthful gunner and show him the weapons with which his ancestors went to war. There was a time when it did good service, it has been heard speaking for the nation in foreign lands, it has borne its honorable share in preserving the Union, but it is unfair now to pit it against the gun of the present.

I propose, then, the Vavasseur 80pdr. as the gun to select for our broadside batteries, and the particulars which I have given demonstrate its ability to discharge all the duty that we could require of a gun in the new conditions of artillery.

The weight of this gun is less than that of the gun it should displace, but the carriage is much heavier than the Marsilly carriage on which our present batteries are now mounted in broadside. Such a gun as the Vavasseur 80pdr. could not possibly be controlled on a carriage alone, it requires a slide besides, as well as all the modern improvements of hydraulic compressors. The carriage which is prepared for this gun has an adjustable automatic compressor which involves much of what you all, no doubt, remember as being the characteristics of the compression used in what has been known as the "Vavasseur gun carriage," united with the hydraulic buffer, which is ingeniously added to the old arrangement. To make myself more distinct—the old Vavasseur compression was produced by revolution of a long screw between the rails of the slide, extending lengthwise, on the forward end of which was fixed an iron cone or disk having metal bearing surfaces sunk into its periphery. This cone or disk worked in a wrought iron drum which had a conical recess bored to suit it similar to a friction clutch. The drum was surrounded by a metal brake strap having a tightening screw with pointer and scale. The grip of this strap on the drum determined the amount of compression, and consequently the velocity of the revolution of the screw, which determined the velocity of the recoil of the gun, for the top car-

riage was connected with the screw by a cast iron nut which clutched the screw, and which was propelled along the screw by the motion, in or out, of the gun and carriage. This was an admirable motion, and the same idea of screw motion is adhered to in the present Vavasseur arrangement of the hydraulic principle, but differently applied.

In his adjustable, automatic, hydraulic compressor Mr. Vavasseur has two cylinders in the use of which the screw principle is introduced by means of rifling the interior. The compressor cylinders rest on the top of the brackets or sides of the carriage of which they form a part; these cylinders are connected together at the rear by a pipe, and are rifled each with two helical grooves. A groove, or score, is turned on the circumference of the piston into which is fitted a gun-metal ring or valve having two projections which fit the grooves of the cylinders. Across each piston and valve are cut two or more openings or passages, making direct communication across the piston from one side to the other.

The piston rods of each cylinder are attached to brackets fixed one at the front and the other at the rear end of the slide. Means are provided by which the piston can be rotated so that the openings in the piston can be placed in any desired position with respect to the openings or passages across the valves; from this it follows that the passages across the pistons can be closed at any desired point.

The piston rods, being attached, one to the front and the other to the rear end of the slide, it is evident that, as the cylinders move during recoil, one piston rod is being withdrawn from one cylinder while the other piston rod is being pushed into the other cylinder, and the liquid displaced by one rod flows through the connecting pipe and exactly compensates for the deficiency caused by the withdrawal of the other rod. This arrangement allows both cylinders and connecting pipe to be kept full of liquid and also entirely suppresses all air spaces. The twist in the grooves is such that while the passages in the piston may be wide open at the commencement they may be nearly, or wholly, closed at the end of the recoil. These passages can be made so large at the commencement of recoil as to reduce very much the strain on the pivot bolt of the slide.

This description gives a general idea of the carriage which is used with the gun that I propose, and one of these carriages is being now used at Woolwich in the experiments that are being made there with the 6 inch R. B. L. Armstrong gun, lately completed on an order from

the English Admiralty. The French Naval Artillery have experimented with this carriage with most successful results with guns of 24 cm. calibre.

It would be impossible to give in more full detail an account of this carriage unless we were provided with detailed drawings, or, better yet, had a specimen carriage under our survey; but enough has been said to show that, great as is the energy of the recoil of the gun that I propose for the main armament of the Navy, a carriage is already provided which is able to restrain and control it within safe limits.

The next point that would naturally have to be considered in deciding on this important question is whether it is practicable to mount such a gun on our ships of war. The question of weight comes first. The 6 inch, 80 pdr. Vavasseur gun weighs 8,624 pounds, the carriage and slide will weigh about 5,000 pounds, making the total weight about 14,000 pounds. In comparison with this we have the weight of the Dahlgren IX in. gun given at 9,000 pounds, and that of its carriage at 1,300 pounds, making 10,300 pounds in total weight. We have an excess of total weight of about 4,000 pounds; is this an objection that merits much consideration? I think not. Let us see what we already have done, in the matter of increasing total weight of battery. Take the armament of the Trenton; she is armed with 8 inch Palliser guns. The "table of elements for various guns" in the Ordnance Instructions gives as the weight of the gun 17,000 pounds, and that of the carriage as 3,790 pounds, and a foot note explains that this is the weight of the top carriage alone; the weight of the slide is probably 4,000 pounds more, which will give us a total weight of this gun, carriage and slide, of 24,790 pounds! This is an excess in total weight over what I propose of nearly 11,000 pounds! If the experiment in the Trenton is only a partial success there can no objection on the score of increased weight, be raised to the change that I propose: and, as the gun is infinitely superior to the Palliser 8 inch, which forms the battery of the Trenton, it could be substituted, with the advantage of increase of power and reduction of weight, for the guns that that ship now carries. This dismisses the enquiry so far as concerns the matter of weight, now as to space, deck room to accommodate the slide.

The length of the slide that is now on trial with the 6 inch R. B. L. Armstrong gun at Woolwich, is 126 inches, or 10′ 6″. Add to this the necessary space between the front of the slide and the spirketting to allow for training, say two feet, and we have a length of 12′ 6″ which

must be accommodated with deck room. We will find, by referring to the deck plans of our ships of war, that we have ample space for a slide of this length on board of all of our 2d rates, except, possibly, in the gangways of the Alaska class, and that nearly all the 3d rates can carry the gun on broadside. The length of slide is admirably fitted for the Quinnebaug class particularly. Here, again, we refer to the slides now in use on board of the Trenton; the slides to which the hydraulic buffer is fitted require a length of 14′ 3″, which, with the space for training, makes necessary a deck space of 16′ 3″. This slide probably could not be accommodated on board of any other 2d rate in the Navy, certainly not by the 3d rates.

We conclude, then, that there is no objection on the score of want of space, and as the builder of the carriages says that he sees his way to reducing the length of the slide still more, we may safely assert that this powerful gun can be mounted on board of all of our ships of war that can deserve the name.

In an early page of this paper I referred to the old binding rule of calibre which had controlled our ordnance under the régime of smooth bores, and in considering the new conditions of things under the régime of rifles, I had dismissed the binding force of calibre so far as range and accuracy were concerned. As the gun that I propose can develop an energy of 2219 foot tons and penetrate 11 inches of armor, I think that I have disposed of any objection that can be urged against reducing calibre on the score of penetration and effect. The fact is that the old expression for energy $\frac{w\ v^2}{2\ g}$ still holds good, we are not deserting our old position; but with the spherical projectile we were limited to a certain velocity, consequently the important factor was the weight which was increased by calibre; but in the present conditions we find that we are not so limited in velocity, and as the energy will increase as the squares of the velocities, while it only increases directly as the weight, it is evident that increasing the velocity immeasurably increases the value of the whole expression, and my position resolves itself into this, that if we can attain a velocity of 2000 feet per second with a 6 inch rifled projectile, weighing 80 pounds, we will have secured a most formidable armament for our Navy. Such a gun can be applied at once to every ship in the service, large and small, and if the larger ones are capable of carrying one or more guns of greater calibre, it would be easy to adopt them, but the great want of the Navy now is a gun for general purposes, to take the place of the IX inch gun on broad-

side, and I know of no gun that more perfectly would supply the demand than this one of which I speak. The gun has passed through all its experimental stages; it is an acknowledged success, and the carriage which is fitted for it has so commended itself to favor that it has overcome all the prejudices of Woolwich, or rather of the English Admiralty, and is now likely to be adopted into the English Navy, for, as I stated, it is now under trial with a 6 inch R. B. L. Armstrong gun made for the Admiralty. The adoption of this gun, which can be used for all purposes, will give uniformity of calibre to our batteries and its light weight will make it a practical substitute for the multitude of small pieces we now have about our ships, as well as for the main battery itself, for it can be worked wherever the slide can be accommodated. The light weight of the gun and the mechanical attachments of the carriage and slide to aid the manipulation of the piece, make it practicable to work the gun with very few men, and thus the whole question of its use at any part of the ship is simply one of space for the slide and strength of structure to support the total weight of gun and carriage.

On the subject of the construction of the gun itself I do not propose to dwell. I am speaking to an audience the majority of whom I believe are well acquainted with the general character of the construction of the Vavasseur gun, and I refer those who wish for more detailed information on the refinements of the manufacture to an article of mine, published with drawings in the July number, 1880, of the *United Service Magazine.* My object is not to present a paper on Construction. I am taking it for granted that my listeners are acquainted with the different rival systems. I am simply presenting a proposition for the adoption of a gun built on the system which I consider superior to all others. I have studied closely the history of this construction from its origin in 1860, I have compared it carefully with rival systems, and I have watched the constant approach of others to its imitation. I have recognized in the progress of the development of other guns an almost total abandonment of the principles on which they were started, while I find in the Vavasseur gun of to-day the same fundamental principles still apparent as they were years ago. I point to unmistakable proofs of the modifications of other manufacture ever approaching the Vavasseur standard, and from all this, having no object but to reach the truth, I have arrived at a fixed and determinate conclusion on the matter of construction, and I feel secure that I have grounds for the faith that is in me. In a word I am convinced, and a man speaking from conviction speaks with no uncertain voice; I approve and recommend the Vavasseur construction.

The particular gun that I recommend is the one which I consider the best fitted for general purposes in a navy constituted of such vessels as will form our Navy for many years to come, and I advise its adoption with a full appreciation of the responsibilty that I assume in advising such an extreme measure, for you will recognize that I propose to advance at once to a point which attains to the highest development of manufacture yet attained. This shows, at least, that I have the courage of my convictions. I see no benefit to be derived from attempting to advance slowly from the low position that we now occupy in artillery, the tentative efforts of other nations are all well known to us, we cannot profit more from our own experience than we can from the well known experiments of others, we are in the favored position of being able to avail of the experience of the rest of the world without incurring the expense of the investigation, and we can adopt the results that these costly trials have achieved. What we want is to recognize facts, to appreciate the necessity of coming to a conclusion, to concentrate on one system, and to act on our convictions.

In urging the adoption of the Vavasseur gun I know that I am placing my opinion in direct opposition to that which has been expressed officially by the Bureau of Ordnance, but I make the issue. The Chief of the Bureau says in his last report, "The only foreign guns which have proved satisfactory are those of Krupp. This manufacturer declines to furnish single guns for experimental purposes; this Bureau has had a standing offer to purchase a 24 cm. and a 15cm. gun for experimental purposes, but does not think it in any way desirable to obtain a further supply abroad. The guns of other manufacturers are not of sufficient excellence to warrant the purchase of even a single specimen." I call attention to the last sentence. This is a sweeping assertion, and we must remember that it comes from a high source. It cannot be pooh-poohed, and brushed aside loosely, it demands investigation. If it be correct, then my teaching is vain. But let us inquire into the truth of this, and let us see who is this Vavasseur who is passed over nameless, in this official declaration.

We first hear of Mr. Vavasseur and the London Ordnance Works in 1860, and for several years his name is associated with that of Captain Blakely for whom was made in 1861 a 64 pdr. built up steel gun which was sent to the exhibition of 1862 in London, and was the only built up steel gun exhibited; Krupp's guns at that date were solid forgings. In 1864, Mr. Vavasseur made 11 inch steel guns for

Peru. These consisted of inner tube of Krupp's steel, reinforced at the breech by a long steel jacket, over which were the trunnions and two layers of steel rings. Three of these guns weighed (each) 12 tons, 17 cwt. Six of these guns weighed (each) 14 tons, 11 cwt.

Comparing these guns with the same size guns now in the English service we have the following points of difference.

	Bore,	Length of bore,	Weight of gun.
Woolwich gun,	11 inch,	145 inches,	25 tons.
Vavasseur gun,	11 inch,	144 inches,	12 tons, 17 cwt.

For the same length of bore we had a gun of half the weight. These guns were proved at Woolwich with charges of 60 lbs. of R. L. G. powder and projectiles of 600 lbs.

In 1866, Mr. Vavasseur built for Peru some 9 inch guns and carriages. These guns compare with the present 9 inch Woolwich guns as follows;

	Bore,	Length of bore,	Weight of gun.
Woolwich gun,	9 inch,	125 inches,	$12\frac{1}{2}$ tons.
Vavasseur gun,	9 inch,	127 inches,	8 tons.

The guns were proved at Woolwich with charges of 43 lbs. of R. L. G. powder, and projectiles of 233 lbs.

At this time, 1866, the largest rifled gun in the English service was the 7 inch breech loading Armstrong gun of 82 cwt., firing projectiles of 114 lbs., with charges of fourteen lbs. of powder.

In 1866, Mr. Vavasseur, with Capt. Blakely, patented the plan of using copper rings, on projectiles, and you will find in the *Revue d' Artillerie* for January 1879, page 329, that Mr. Vavasseur is given credit for first employing copper rings practically on projectiles.

In 1867, Mr. Vavasseur first employed the plan of putting the breech mechanism in the jacket instead of in the tube of the gun, a subject on which I remarked in the July number of the *United Service Magazine* for 1880 to which I called your attention above.

In 1879, Mr. Vavasseur sent to China ten 7 inch guns and a number of smaller size; in 1880, he had in hand twelve 7 inch guns and some 40 pdr. B. L. guns.

In all, there have been turned out from these works a thousand built up steel Vavasseur guns, in which the principle of the original construction has never been departed from, which have all been successful guns and which have never been known to burst nor to cause disaster. These guns have been bought by Peru, Mexico, the Argentine States, China, Japan, France, Portugal, Russia, and Spain (by the

last two for experimental purposes only). Truly, I may safely demur to the assertion of the Chief of the Bureau of Ordnance when he declares authoritatively that, with the exception of those of Krupp, "the guns of other foreign manufacturers are not of sufficient excellence to warrant the purchase of even a single specimen." I may have great confidence in the opinion of the Chief of the Bureau, but I am not willing, at his dictum, to condemn that of the experts of all the nations whom I have mentioned as customers of Mr. Vavasseur. The Vavasseur gun can be bought, it is in the market like any other article of manufacture, and I recommend the purchase of samples at least; and I do not allow myself to be carried away by the idea that, because Mr. Krupp makes the most guns, his guns are necessarily the best; I believe that the Vavasseur gun is the better, and I recognize all the improvements in the late manufacture of the Krupp gun as being borrowed from the Vavasseur construction. The disposition is shown on the part of the Bureau to go so far in the way of making a purchase as to be willing to buy a gun from Mr. Krupp, but if he chooses to decline to fill the order I can see no reason why we should permit him to block the way to our purchasing from another merchant whose goods are approved by the very responsible parties that I have enumerated. No good reason can be given for excluding the Vavasseur gun from consideration in this case except want of information on the subject of the manufacture, and on the capacity of the London Ordnance Works to fill any order that may be given to it.

Now as to the objection that will be made by some to my proposition, although the objection has no weight with me for reasons which I will give, that, in order to adopt the gun that I propose, we must purchase abroad. That the gun must be made of steel, if we are to adopt a gun of the highest development, no one will deny, and we cannot supply the material from our home manufacture. These assertions are endorsed in the last report of the Chief of the Bureau of Ordnance of the Navy in which, in relation to the first, he states distinctly his "opinion that steel is the proper material for our armaments." In relation to the second assertion that the steel cannot be produced in the United States, the Chief of the Bureau reports as to his test of the capacity of the machine shops in the country, in December 1878, when only one steel manufacturer could be found who would undertake to furnish an ingot for a 6 inch gun, and it is inferred from the remarks in the official report that the ingot is not yet delivered; and we may safely conclude that it would not be satisfactory if it were delivered, for we could hard-

ly expect success to attend a first effort in such a new industry. This is a practical confirmation, if such were necessary, of our assertion that we cannot produce steel for cannon tubes. But is this a good reason why we should remain unarmed? Is the craze of protection to be carried so far that, because we can only manufacture bows and arrows, we are to avoid profiting by the manufacture of others in order to provide ourselves with means of defense? This is the acme of folly. Why should we wrap ourseleves up in our weakness and decline to buy steel for our defense? I can conceive of no satisfactory reply that can avail at any time except when we may be engaged in war; then, of course, it is desirable that we should be found able to make our own war material, but in time of peace, as now, I see no reason why we should not purchase abroad. On the contrary, I see every reason why we should take advantage of the present time to provide ourselves from abroad, as it will be the only course, by which we can force the way towards future independence in the matter when it might become necessary for us to depend on our own resources. There is no doubt that it is within the resources and the capacity of our manufacturers to supply us with the material that we require, but they will not do it, because it won't pay. So long as we are content to go along in this *laissez aller* way, showing no determination to bring about a change, we allow ourselves to remain captive in the hands of our manufacturers who force us to take what they choose to supply us with, and our efforts are limited by the character of the material which they provide; but if they recognize that a change is determined on, and if they see us throw off the weight that they put upon us by their want of enterprise, and if they see us providing ourselves from foreign manufacturers, then indeed they may be roused to effort, and they know that successful competition would naturally bring back the custom of the Government to the home manufacture, and we would achieve the independence so desirable in this matter; but it will require some such incentive as this to force our manufacturers to incur the expense and labor of developing the manufacture of the steel which is indispensable for the tubes that we will require. It is my belief in the effect of this means of incentive that makes me counsel the purchase of foreign guns and carriages at this time; and I think that this object should be sufficient to silence all protests against foreign purchase. Besides, such a course will enable us to show to our own manufacturers exactly the material and the articles that we require, and they can enter into the competition with a full understanding of what it is that they are expected to produce.

I will recapitulate in as few words as possible. My first impressions were received and my opinions formed in the "Old School." The workings of my mind favor conservatism. I cannot be a radical in the common acceptation of the term. I would not cut myself adrift from old moorings without seeing my course clear. I grew up in the Navy with the smooth bored cannon; I saw it pass through its phases until it reached its point of perfection in the Dahlgren gun. I was a firm advocate of calibre even to the discomfort produced by manipulation of heavy projectiles. I was convinced that energy must be developed, and the only available way to do this was to keep up the calibre to the highest practicable point. The system of rifling was applied to cannon, and I find that in order to sustain the indispensable requisite, energy, it is not necessary to adhere to increase of calibre, as, under the conditions of the rifled system, the other element, velocity, which was limited with the smooth bore, and which with weight goes to make up total energy, can be indefinitely extended. I find myself in a new dispensation which does not require me to desert my old faith. In recommending a total change under the new conditions I feel that I stand firm on the old platform which has ever proved to be secure.

I hold that the change in our ordnance need not be delayed in consequence of the seeming undetermined character of our ships of war; as I believe that, for years to come, the style of our ships is already determined; and the gun that I propose as worthy of our first attention is the one of which we require the greatest number. In adopting such a piece we can the more rapidly effect the change required; and the convenient size of the gun will assist to relieve us from our present embarrassment consequent upon mixed batteries. I incidently remark on the uselessness of most of the light pieces on uncovered decks in consequence of the development in machine guns. I think that the gun that I propose has not been brought to the fore in this country in consequence of lack of information on the subject of its manufacture and of its service, and I have given an outline history of both. The great difficulty that the London Ordnance Works has had to contend against in England has been the overpowering influence of the Armstrong interests, which has entirely actuated the Woolwich clique, and has constrained the English government to throw its whole weight and influence on the side of the wrought iron, muzzle-loading gun; but you all know that this error is being recognized, and that the force of public opinion is now forcing the Woolwich authorities to advance in the direction of steel and breech loading. On the continent the éclat

of the Krupp manufacture, and the personal support of the German Emperor has enabled Mr. Krupp to pass all competitors of more moderate means for expansion. Thus Mr. Vavasseur has not found customers among those nations likely to bring his guns prominently to the notice of the world, but the long list that I have given of those who have used his guns shows that they are not without admirers, and that its advantages are not unknown. I feel very sure that, if the Bureau of Ordnance could have been induced to consider the Vavasseur gun of "sufficient excellence to warrant the purchase of even a single specimen," it would have, ere this, commended itself to the intelligence of the Navy.

THE CHAIRMAN:—I am sure that every one present will join me in offering our most hearty thanks to the distinguished officer to whose paper we have just listened with gratification and interest. He speaks with authority on all connected with Ordnance for he has made it his specialty, and has written upon it with large acceptance. I am not however, prepared to accept the plan of arming our ships of war with the Vavasseur gun. Its maker is honored as a very skilful mechanician, and his works are well known to the world and have a well deserved repute. His guns have been long offered for sale, and have from time to time been purchased and tried, but I do not know that they have been largely adopted even by those who have made purchases of them.

Some were bought by Peru and were lost in the "Independencia". They certainly have not found, so far as I know, acceptance on the Continent or in England, though perhaps the extreme conservatism that has hitherto prevailed in England gave little chance for competition with the Woolwich gun.

The success of Krupp on the Continent, has at last driven the English government to doubt its favorite gun, and it is now making new cannon of increased length, breech-loading and with large chambers.

Mr. Trevelyan, the Parliamentary Secretary of the British Admiralty, has recently stated in his speech on the Naval Estimates, that the new gun of this class, weighing eighteen tons, will pierce 13½ inches of armor at 1000 yards, thus doing the work of the 38 ton guns now in use in the British fleet. Even under the great desire to compete with the Continental navies and surpass them, England has not adopted Mr. Vavasseur's plans.

Above all things, it seems to me, we need gun makers, and that we should not buy our guns abroad, but should make them ourselves. In the event of foreign war, with our enormous sea coast and defenceless bays and harbors, we need greatly the ability to manufacture guns for their protection, and no matter what it may cost, or how difficult it may be, we should create a class of skilful gun-makers ready to supply the wants of the country in its peril. Our people have shown much energy and skill in the working of steel, and although they have not been successful hitherto in making steel guns, their ingenuity should be fostered in this direction and our national strength and

resources thereby increased. Gun makers would be worth to us all they might cost.

We all agree with Commodore Simpson in his opinion as to the deplorable condition of our Navy as to guns, and sympathize cordially with him in his desire to re-arm our ships with long ranged, breech-loading cannon of the best type.

In the name of the Institute I now have the honor to offer formally its best thanks to Commodore Simpson for the pleasure and instruction he has given us.

THE USE OF STEAM IN THE MANUFACTURE OF GUNPOWDER.

In 1862 or 1863, Col. G. W. Rains introduced into the Confederate powder mills at Augusta, Georgia, a most valuable improvement by which the process of mixing was made so much more thorough that the time required for incorporation was reduced three-fourths. The sulphur and charcoal were severally pulverized and bolted; the nitre, pulverized by disturbed crystallization, was added to these, and the mass, roughly mixed, was moistened with water and introduced into horizontal cylinders of sheet copper, 30 inches long by 18 inches in diameter. These cylinders revolved slowly on a common axis consisting of a heavy brass tube 3 inches in diameter, perforated within the cylinders by a number of holes one-eighth inch diameter. High pressure steam was introduced through this tube, raising the temperature to the boiling point, while the water produced by condensation, added to that originally used to moisten the materials, reduced them to a semi-liquid slush, which was run out of the cylinders after about eight minutes' rotation. On cooling, this mud became a damp, solid cake, the nitre, which in the state of boiling hot saturated solution had entered into the minutest pores of the charcoal, now recrystallizing. The cake so produced was transferred to the incorporating mills, and, under 5-ton rollers, was in an hour brought to the condition of finished mill cake, ready to be cooled and granulated, while, without the steaming process, four hours' incorporation in the mills had previously been necessary to produce powder of the same first-class character. The capacity for work of the mills was thus practically quadrupled, the thorough saturation of the charcoal with nitre being accomplished by the steaming, while it remained for the rollers merely to complete the mixture of the whole mass and give the required density to the mill-cake.

Am. Chem. Jour., Vol. 2, No. 6, p. 423.

PROFESSIONAL NOTES.

These articles have not been read before the Institute but are inserted by order of the Executive Committee.

DEFLECTING ARMOR.*

To obtain the best results deflecting armor should have a hard, smooth surface, and possess sufficient rigidity to turn the ends of shot and bring them sidewise against it; the great penetration obtained by elongated shot is due to the concentration of energy on the small area of their cross section. The area of a longitudinal section of a shot of three calibres' length is almost four times as great as the area of the cross section, consequently the penetration of such shot would be proportionally reduced if they were made to strike on their sides. If the armor does not possess a hard surface, the local give will permit the ends of the shot to bite and the armor will be penetrated. Armor of a proper thickness, having a hard, smooth surface, disposed at an acute angle, will possess considerable elasticity when struck by shot, by yielding bodily to it. Even if the entire energy of shot is absorbed by armor, if the shot is made to strike upon its side, it could be resisted with a moderate thickness of armor.

The greater the difference between the length and the calibre of shot —other things being equal—the more easily the shot can be turned, for there will be less weight in the end. It may be assumed that the entire weight of the shot is resident in its centre of gravity, and as the leverage is greater in a long shot, it would be more easily turned than a short one of equal weight. Great penetration is obtainable only with shot of great length in proportion to their diameter, but increased length implies increased area of longitudinal section, consequently if the end of the shot is turned by deflecting armor, the advantage of increased length is completely neutralized by increased surface of impact.

Owing to the perishable nature of wood, when used as backing for armor, it is desirable to avoid its use, but wood can be applied with as

* See article on Deflecting Armor in No. 15, Vol. VII, Proceedings of the Naval Institute.

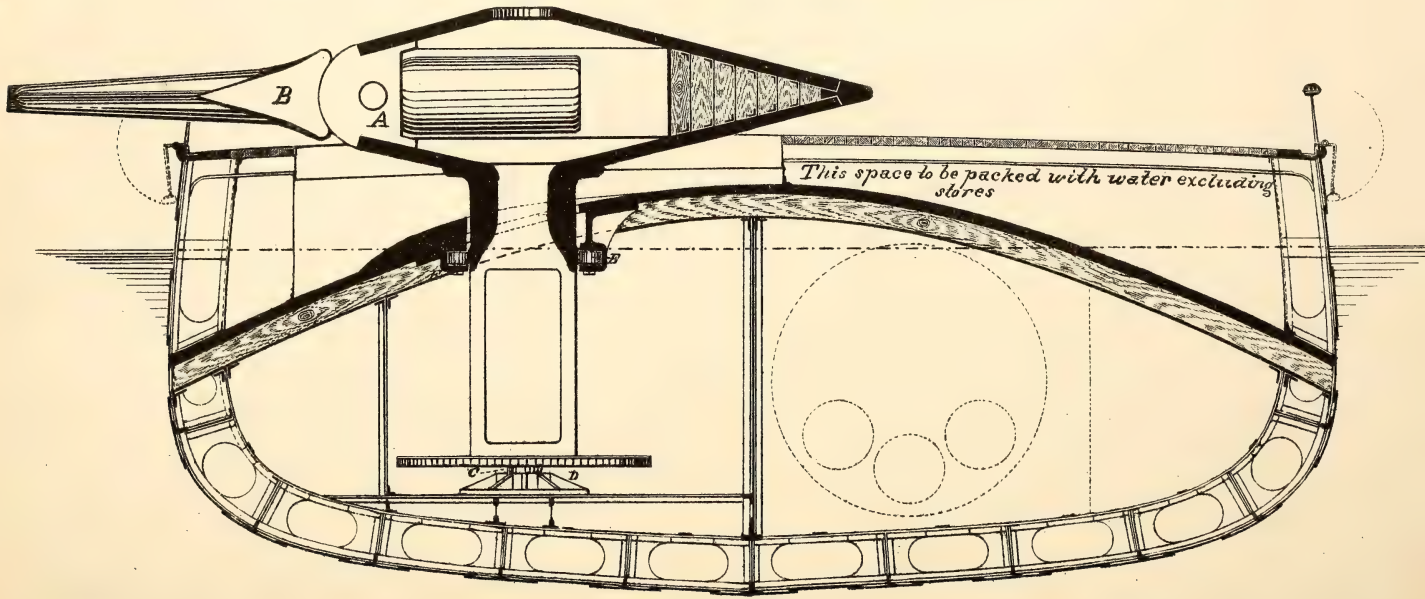
great advantage as backing to deflecting armor as to the vertical type. The Interior Shield, or turtle back, composed of compound armor, having a hard, smooth surface, could be supported on beams of wood eight or ten inches thick, bent to the curved form, bolted together, and secured to the vessel's sides.* If found desirable the Deflecting Turrets could be filled up solid with wood, except the space in the centre between the guns, where the men stand to operate them; with the hydraulic appliances for loading the guns very little space inside the turrets is necessary, two men to manipulate the hydraulic gear of each gun being all that would be required, together with an officer to direct them. The latter could operate the valves regulating the hydraulic power by which the turret is rotated, and by means of observation slits he could keep the guns constantly trained on the enemy, and the operations of loading and firing could go on uninterruptedly, as the loading apparatus would revolve with the turret. There is ample room in the double convex turrets for an officer and four men, and in event of casualty a relief force could be promptly sent into the turret from beneath the Interior Shield.

The great length now given to guns renders the adoption of the breech loading system necessary, as it would be almost impossible to load guns of such inordinate length from the muzzle; it is also impossible to protect guns of such great length with armor, and to keep the weight within practicable limits. Guns are now made as much as thirty calibres in length, this proportion if applied to the 100-ton Armstrong gun which has a bore of 17.72 inches would give a length of 44ft. 3in. These long guns give the best results, but as it is impossible to make turrets of sufficient size to protect them, their most vulnerable parts, the muzzle ends, would be entirely exposed, if they were used on ship board. It is therefore proposed to make the guns in a deflecting form, by which a very fair measure of protection can be obtained with a minimum of weight. Fig. 1 represents a plan view of a double convex turret with two guns mounted in it. Fig. 2 represents a cross sectional elevation of the same turret on the line *a b* showing the cross section of vessel and turret, with a gun in elevation.

The guns in this turret are mounted on trunnions and oscillate for elevation and depression on heavy trunnion blocks A, which are firmly secured to the armor casing of the deflecting turret, the guns therefore

* The wood backing under the Interior Shield, as well as that filled in the deflecting turrets, could be taken out if it became decayed, and renewed without impairing the integrity of the vessel.

Fig. 2



have no recoil and the thrust of the discharge is received on the trunnions and on the joint J, fig. 1, made by the junction of the gun with the trunnion block A ; this joint is an arc described from the trunnion centre. Fig. 3 shows a cross section of one of the guns near the muzzle. The deflecting form given to the guns would make it difficult to seriously injure them by side shots. The guns are set back in the armor of the deflecting turret so as to brace them against side shots. At this point the side of the gun presents a flat surface B, fig. 2, to a similar surface of the turret armor. Fig. 4 represents a cross section of a gun on the line *e f* showing the flat surface presented by the side of the gun to the turret armor, by which it is braced against side shots.

Recoil for naval guns was of great advantage with muzzle loaders, as by it the guns were run in to reload, but with breech loading guns there is no good reason why it should not be entirely done away with; unless it is retained for the purpose of automatically opening the breech to reload, which would be hardly warranted by the advantage gained. Guns will throw shot with somewhat greater force if they are not permitted to recoil, but the great advantage in doing away with the recoil would be the much greater simplicity, and by having the guns firmly secured to the armor, there would be no danger of their getting loose in a sea way, and they could therefore be used under circumstances that would preclude their use if they were mounted in the ordinary manner so as to admit of recoil. With guns firmly secured to the turret armor the shock of the discharge would be communicated to the entire turret, and as the turret rests on a central spindle C, fig. 2, stepped in a hydraulic press D, supported by the keelsons of the vessel, and is firmly supported laterally by the Interior Shield, or turtle back, the shock would be distributed over the entire vessel, and if the guns were discharged abeam, it would probably roll the vessel a few degrees in line of recoil. In an ordinary vessel it would not be expedient to mount heavy guns without providing for recoil, as the ship would most likely receive serious damage from the shock of their discharge, but a vessel fitted with an Interior Shield is braced in such a manner as to endure such shocks without receiving injury. Mortars are mounted without providing for recoil, and, when on shipboard, their platforms are laid up solid from the vessel's bottom. The lateral support afforded by an interior shield will give ample bracing to admit of the mounting of heavy guns without recoil.

While the double convex turrets with deflecting guns would seem to be best adapted to the heavier class of vessels, to be used for coast de-

fense, and to operate against forts and land batteries, the V shaped turrets would seem to be best adapted to cruising vessels.

Fig. 5 represents a deck plan of a vessel with two V turrets. These are intended to deflect shot laterally and admit of mounting the largest size gun; one gun being mounted on each turret en-barbette. The turrets are erected on circular platforms, in circular hatches through the Interior Shield, which supports them laterally by means of anti-friction rollers, protected beneath its edge. The turrets are to be supported on central spindles, stepped in hydraulic presses resting on the keelsons of the vessel, and are to be rotated by hydraulic power, the valves regulating which are to be under the immediate control of the officer in command of the gun, who can keep his turret trained so as to receive all shot at a deflecting angle. So long as shot come from only one direction, and the gun is kept trained in that direction, this form of turret will be practically invulnerable; for it admits of a thickness of armor that will be found impenetrable at an acute angle.

By the aid of hydraulic power these turrets can be rotated with great celerity and precision and held firmly in any desired position by the officer in command of the gun, and so long as he has but one adversary to contend with, and he keeps his gun trained against him, his armor cannot be penetrated.

It is within the bounds of possibility to build a vessel of very moderate size on this plan, fitted with an Interior Shield for the defence of the water line, the crown of which would rise amidship about a foot above it, and would present a practically constant angle of impingement to horizontal shot at the water line, as the vessel rolled; with two V turrets having on each a large rifle of great length. Such a vessel having superior speed, which would enable her to choose her own position in combat, say from 300 to 500 yards distance from her adversary, would be more than a match for any vessel clad with vertical armor now afloat. She could drive her shot through the vertical armor of her adversary, who in return, at that distance, could not strike her at a penetrating angle. So long as her opponent could not chase down, and fire plunging shot into her from guns depressed, it would be an unequal combat with great odds in favor of the vessel armored on the deflecting system; but even if her adversary possessed the speed necessary to force her to fight at very close quarters, where they would exchange plunging shot, if the vessels were of equal size and armament, the ship armored on the vertical system would possess no advantage.

A vessel armed with two large guns mounted on V turrets, one on

Fig. 5

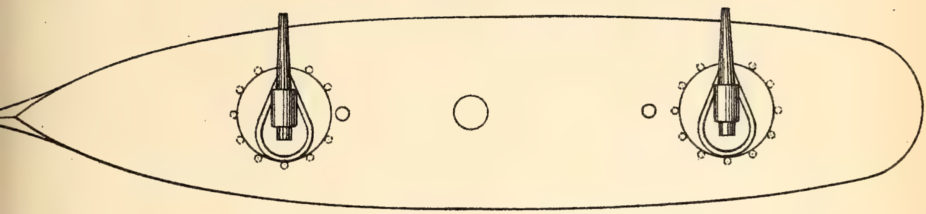


Fig. 4

Fig. 1

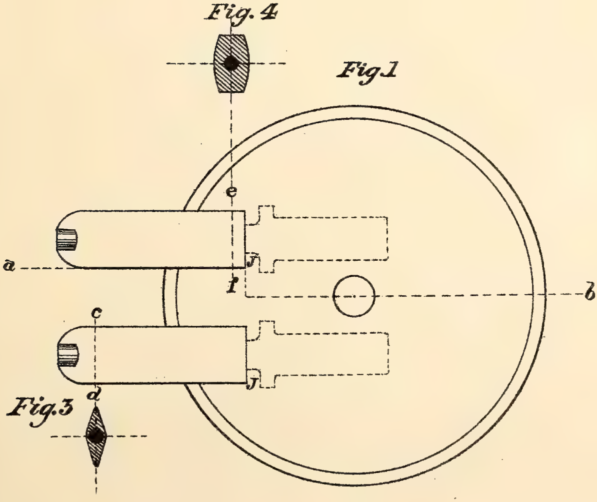


Fig. 3

each end, would have the advantage of an all round fire; and would be able to train both guns sharp on the bow, or over the stern. A vessel having but two large guns, it would seem to be a better arrangement to have them mounted separately, than to have both guns in one circular turret where a single shell striking the turret near right angles, might kill or disable the crews of both guns and lead to the loss of the vessel.

Vertical armor protects by deflection only, whenever it is struck at near right angles to its surface it can be penetrated, and the only protection to be obtained is to so dispose the armor that it cannot be struck except at a deflecting angle, thereby presenting the much greater area of the longitudinal section of the shot to the armor, and throwing it off. Shots are apt to be deflected downward as well as upward, and a flat armored deck situated at or near the water line, which would be liable to receive shot under it as the ship rolled, and which would be inclined so as to deflect them downward through the magazine and boilers, would be a positive source of danger to a vessel fitted with it.

N. B. CLARK,
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THE BOMB THAT KILLED THE CZAR.

Since the assassination of the Czar we have looked with interest for a description of the weapon used by the assassin as it was rumored it was of novel construction and of great power. All attempted descriptions that we have met have been meagre and imperfect, the most detailed, and that claiming the greatest accuracy, being found in *Le Gaulois* of March 29th. From this we gather that the bomb consisted of a sheet iron cylindrical box 15 cm. high and 10 cm. in diameter. On the left hand side was a copper tube 9 mm. in diameter and extending the whole length of the box from top to bottom. This enclosed a hermetically sealed glass tube of equal length and 3 mm. in diameter, which was filled with sulphuric acid. The space about the glass tube within the copper tube was filled with a mixture of Berthollet's salt and a salt of antimony. At the longitudinal centre of this copper tube its diameter was increased to 3.1 mm. for a distance of 1.9 mm., in order to admit of a disc of lead of slightly smaller dimensions which was perforated and free to slide a small distance on the glass tube. This lead disc was intended to break the tube by its impact when the bomb was arrested in its flight and thus liberate the sulphuric acid. From the side

of this enlargement in the copper tube another tube 4 mm. in diameter filled with pyroxyline led across the box to a copper tube 1.6 mm. in diameter and 35 mm. high, filled with gun cotton, placed in the lower right hand corner of the box. All of the rest of the space in the box was filled with nitro-glycerine. This is a very crude description and undoubtedly in some respects incorrect, but it may, in the main, fairly represent the construction. As Berthollet's salt, an ammoniacal salt of silver, is so sensitive as to be readily exploded by the least touch, it is improbable that it should have been used, and if used the salt of antimony and sulphuric acid would have been unnecessary, but it is probable that a mixture similar to that used in the Harvey torpedoes was employed. The distinction between pyroxyline and gun cotton is also vague.

C. E. M.

REVIEWS.

No publication will be noticed under this head, unless a copy to be deposited in the library of the Institute is sent to the Corresponding Secretary, at Annapolis, Md. All reviews must be signed by the writer.

THE NORDENFELT MACHINE GUNS (PALMCRANTZ'S SYSTEM). JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION, NO. CVIII.

In these days of many men of many arms, when—as a rule—no inventor thinks any other arm is in any way to be compared with his own, it is quite remarkable to find any machine gun authorities agreeing in a comparison, even in a general sort of way.

In a pamphlet on the Gatling gun, published in 1874, it is stated that "The same class of men who doubted that the railway would ever take the place of the stage coach, ...; the spinning jenny of the time honored spinning wheel, ..., may dogmatically decide in the negative" anent the necessity of using machine guns; and last June (1880), Mr. Nordenfelt in a paper read before the Royal United Service Institution stated that "Machine guns are to the art of war what Arkwright's spinning jenny was to weaving". When we come to inquire which one of the machine guns most nearly answers to this description, we are met by so many very different and equally emphatic assertions, both as to points of comparison and as to what constitutes excellence, that we are in self defence forced to accept the dicta of some one authority, or form our opinions in accordance with procurable evidence. This last is found to be almost impossible because the best evidences, official reports of both service and proving ground tests and trials, seem to vary with an, as yet, undetermined function of the longitude of the place of such tests and trials. If, however, we accept Mr. Nordenfelt as such an authority, it would appear from his paper that the Palmcrantz system of machine guns is better adapted to fulfil the requirements than either the Gatling or the Gardener. But in regard to this it may be well to consider some of the points presented.

We learn that the "supposed difficulty of supplying ammunition for a machine gun in the field is not great—always granting that the gun uses the same ammunition as the rifle; because. . . . ., the total ammunition fired from the machine gun would probably not exceed what would have to be fired by the corresponding number of rifles before the same object were gained".

Evidently the "corresponding number of rifles" does not mean the number corresponding to that of the barrels of the machine gun; for, if a Nordenfelt five barrelled gun could not, under favorable circumstances, gain a greater object than five riflemen, there would be no earthly excuse for its existence; the meaning would seem to be that the amount of ammunition used, by a machine gun on the Palmcrantz system, to gain a certain object would probably equal that used by rifles to attain the same object, and could be just as readily supplied; so that if the machine gun fired—as it should to be efficient—as fast as one hundred riflemen, who march loaded down with cartridges, it could be readily supplied by one hundred men carrying ammunition; but it is difficult to understand just where these hundred men are to come from when we are told that "six or eight men" constitute a gun's crew; nor is it plain how ammunition, ready for firing, can be more easily transported in the bulky and heavy Nordenfelt magazines than in the light, compact, cartridge-factory pasteboard packages for use with the Gardener and with the Gatling when the *feeder* is employed.

"I hope", says Mr. Nordenfelt, "that Dr. Gatling will excuse my saying that his revolving gun with movable breech supports, is tied down to the first part of my second basis of division, viz., that his gun can only fire rifle [musket calibre] ammunition with advantage". The application of this remark is not quite clear in face of the fact that for more than a decade Gatlings of 1″ calibre have been in use, in many parts of the world, have fired their projectiles with more or less "advantage", and have never, it is believed, killed any one standing in rear of them. Nor is it easy to understand why the breech supports of the Gatling are more movable than those of the Nordenfelt; for if by "breech supports" the action block and breech pins are meant, they must be movable as are the Gatling locks, in order to allow the chambers to be loaded. Mr. Nordenfelt himself says "when the block [the action block] is moved forward, these [the breech pins] push forward the cartridges etc,"—just as do the Gatling locks; but, at the moment of firing, the Gatling system receives the shocks of the successive explosions upon the solid recoil piece fixed upon the immovable cam,

while the Palmcrantz takes up the recoil of a whole volley upon the action block which "is moved forwards and backwards by the action of the firing handle."

It is curious to note that Mr. Nordenfelt's remark, "The Hotchkiss gun is a development of the Gatling idea," is almost an exact expression of Dr. Gatling's opinion, were we to substitute *Nordenfelt* for "Hotchkiss" and *an arrested* for the indefinite article; and indeed, if one compares the plan of the Palmcrantz system with that of the Gatling, developed upon a plane, as shown in a Gatling Gun publication of 1874—the date of the appearance of the Palmcrantz system—it is not very difficult to understand upon what the Doctor bases his impression, an impression it may be mentioned in passing, quite different from that of an American naval officer, who, being asked upon the appearance of the Palmcrantz what it was like, said, "Why, it's just the old Requa battery, that Gilmore used at Charleston, a dozen years ago, with a slightly improved feed."

When Mr. Nordenfelt said "I would, however, hardly class the Gardener gun with machine guns, because the single barrelled gun Mr. Gardener himself especially recommends is rather a clever repeating rifle, while it at the same time requires the full service of men and equipment of a machine gun," he was probably not aware that at the time he spoke, the Gardener system was being applied to four and five barrelled guns, or that the system was particularly applicable to two barrelled weapons, which, with less than half the number of barrels and with a corresponding decrease in weight have equalled what Mr. Nordenfelt calls the "tremendous rapidity" of fire of his light five barrelled gun, viz., five hundred rounds per minute. He was, however, quite correct in stating that this "clever [double barrelled] repeating rifle" would require the full service of men and equipment of a machine gun; but it is not clear why this should be considered an objection to the arm as compared with the Nordenfelt, since "the full service of men and equipment" can with equal ease transport ready for firing at least twice as much ammunition in the Gardener packages as in the Nordenfelt magazines.

We notice in regard to the working of the Palmcrantz that "one single gunner can fire without any assistance, with his right hand rapidly, an entire hopper full of cartridges, while his left hand is free to attend to the elevating and traversing gear," and that "with the comparatively slow movement of the mechanism no jams nor hitches are likely to be caused by the mechanism." The first of these considera-

tions would seem to be of questionable desirability, since the average man has sufficient occupation in either pointing or firing; and since, unless the mount be very awkward, the man who fires cannot get his eye down to the line of the sights while in position to exert his full power on the firing lever or crank—but both points are common to all machine guns of any prominence.

By the "regulator" for the Gatling, Mr. Nordenfelt evidently means the adjusting nut; but that the use of it "requires great judgment on the part of the gunner" is not, in the light of experience in our Service so evident. The writer once assisted in firing sixty four thousand cartridges, in a single day, from an old model Gatling—which was not regulated or wiped out during the trial—but failed to note that the regulator gave trouble: with the rear adjusting nut that has been in use some years, it is hard to conceive what the "trouble" Mr. Nordenfelt speaks of could possibly be.

We can understand Mr. Nordenfelt's arguments in favor of the use of mitrailleuses—by which term he designates musket calibre machine guns in general—because we have been accustomed to hear them from machine gun admirers for the last fifteen years; but when he illustrates the superiority of his particular gun, the light five barrelled Nordenfelt, by saying that it fires "about five hundred rounds per minute, or, for spurts of one hundred shots at a time, at the rate of nearly eight hundred shots per minute", we are again hopelessly adrift as to the point of supremacy; for the two barrelled Gardener, as made in the United States, is fired with equal rapidity, while the light navy Gatling fires fully one thousand rounds per minute, or, for spurts of forty shots at a time at the rate of fully twenty four hundred shots per minute.

The following table shows the comparative weights and rapidities of five of the Nordenfelt and Gatling systems according to figures furnished by Mr. Nordenfelt, and from United States official sources.

10 Barrelled Guns.

System.	Weight.	Rapidity.
Nordenfelt.	280 pounds.	110 rounds in 5 sec.
Gatling (U. S. Army).	198 pounds.	40 rounds in 1.25 sec.

5 Barrelled Guns.

System.	Weight.	Rapidity.
Nordenfelt.	110 to 135 pounds.	70 rounds in 5. seconds.
Gatling (U. S. Army.)	100 pounds.	40 rounds in 1.75 sec.

The short ten barrelled navy Gatling fires more rapidly than either of the army guns above mentioned ; the model was determined upon as that which would give the best results for general use aloft, on deck, or ashore, and is apparently fitted for all the kinds of work that Mr. Nordenfelt assigns to both his light five barrelled and heavy ten barrelled musket calibre guns for naval uses.

Mr. Nordenfelt assumes that 1″ solid shot are the proper projectiles for anti-torpedo boat guns in opposition to the generally received opinion which seems to favor 1.″5 calibre shells; but we can readily follow his reasoning upon the point in question, and when he says, after clearly giving the probable conditions under which the guns would be needed, " it is the volley, with the slight spreading caused by the vibration of the weapon, which gives me the best chance of hitting," it is clear that he is right—provided that we are considering the chance of a single shot to a volley. But if we are considering the chances of making a hit in a given time during which a certain number of rounds can be fired, and at all instants of which the chances are equal that adverse circumstances shall render futile any single attempt, the volley fire does not seem to have all the advantages over the continuous ; and, indeed, it would even seem that the supremacy of the four barrelled 1″ calibre, solid projectile throwing Nordenfelt gun could be granted only on the hypothesis that among the varying conditions of practice at sea, which Mr. Nordenfelt so clearly describes, the Palmcrantz system shall always be fired at the right instant, while the revolving system gun shall be fired at the wrong time, three times out of four. This as regards the 1″ calibre solid projectile guns ; but if we compare the chances of hitting when the revolving system gun throws 1.″5 calibre shells, even if we limit the number of shell fragments to four, the superiority of the volley fire would seem to disappear when considering only a single instant and single attempt ; and therefore we can easily understand how in the United States, in France, in Germany, in Denmark, and in many other countries, there might be held the theory that the 1″.5 Hotchkiss was a better anti-torpedo boat gun than the 1″ Nordenfelt ; a theory that is proved to be all wrong by the reports of official trials off Portsmouth last year, published by Mr. Nordenfelt, and all right by the reports of official trials in the Helder the year before, published by Mr. Hotchkiss. The following extracts from these reports will illustrate the general way in which longitude, as stated above, affects the action of machine guns.

Results of firing against Torpedo-boat Models at Sea during a Single Run. Guns in both cases mounted side by side and worked for the same time and under exactly identical circumstances.

Gun.	When.	Where.	Shots.	Hits.
Nordenfelt.	1880.	Off Portsmouth.	118.	62.
Hotchkiss.	"	" "	52.	11.
Hotchkiss.	1879.	The Helder.	132.	54.
Nordenfelt.	"	" "	85.	12.

If by repeated trials Mr. Nordenfelt proves that 1″ calibre solid shot are the proper projectiles for anti-torpedo boat guns, the Gatling Gun Co. will probably begin to manufacture its 4 barrelled 1″ calibre solid steel projectile gun of three and a half hundred weight, designed some half dozen years age but never manufactured because the demand for guns using such projectiles did not warrant the expense of change of model and plant.

The lack of detail in Mr. Nordenfelt's mention of his 1.5″ calibre single barrelled gun makes it difficult for one not familiar with its merits to understand in what way it is superior to the service 1.45″ Hotchkiss or the single barrelled Gatling of that calibre.

Having followed Mr. Nordenfelt thus far, it may be well to notice the points of superiority claimed for other systems of machine guns. Admirers of the Gatling system claim that for musket calibre guns, it is superior to the Palmcrantz in that it furnishes greater rapidity of fire; is lighter; less awkward in shape for work in tops, boats, and other confined spaces; protects its mechanism better; is more enduring; furnishes continuity of fire at such a rate that all the good effects of a volley may be attained without undue recoil; allows the piece to be kept constantly bearing on the object while the fire is constant for an appreciable time, even in spurts; uses ammunition from a neat feed case, easily handled aloft and in confined spaces, or from cartridge factory packages.

The supporters of the American Gardener system claim that it is superior to the Palmcrantz in furnishing double the rapidity of fire per barrel; in giving a continuous fire; in being neater, lighter, and better protected in its mechanism; in being more enduring, since it is not strained by volleys; and in not requiring its ammunition to be stowed in magazines, in order to have it ready for firing.

The service Hotchkiss among other claims for superiority over the

1″ calibre Palmcrantz has the following: continuity of fire; greater ease of pointing, and consequent greater chance of hitting, other things being equal; capability of being kept bearing on a swiftly moving object and not being thrown off by volley firing; greater safety to gun's crew, and more practical mount; while in general, in the words of a Danish officer who reported on a competitive trial to the Minister of Marine, "The Palmcrantz gun was proved by the trials to be in action far inferior to the Hotchkiss revolving cannon."

But if Mr. Nordenfelt was so confident of the supremacy of the Palmcrantz system last June, how much more so must he be now, since it has so cleverly won nearly all the laurels of last winter's trials at Shoeburyness; trials which really ought to teach something as they were made without the use of the wrapped metal cartridge. Under the circumstances it is natural that he should exclaim, "I cannot speak too highly of the trials in England"; while it is perhaps not unnatural that Dr. Gatling with his gun, possibly feeling the malign influence of the longitude, should remark, "From information I have obtained, I judge that the late trials of the machine guns at Shoeburyness were poorly conducted and that great injustice was done the Gatling gun."

The official reports of these trials must be very favorable to Mr. Nordenfelt's guns, but whatever they are to be, it seems that they will not decide the adoption of any particular system in England, for already a new machine gun committee has been appointed to institute renewed trials.

From what little information the writer has been able to gather, it would seem to him that the Nordenfelt guns are very excellent weapons and that they are growing in excellence; as, for example, in the matter of the locking of the trigger comb, which will, it is thought, tend to prevent a repetition of the embarrassing and disagreeable occurrences, which took place on board H. M. Ships "Comus" and "Northampton." It does not appear, however, that they are in any respects superior to the machine guns adopted for use in our Navy.

W. W. Kimball, Lieut. U. S. N.

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AMERICAN ACADEMY OF ARTS AND SCIENCES. PROCEEDINGS, VOL. XVI, PART 2. The bolometer. Prof. S. P. Langley formerly of the Naval Academy has invented a very ingenious and delicate instrument which he calls the bolometer oractinic balance. The determination of the relative amount of energy, in the form of heat, light and actinic rays, in the different parts of the spectrum has engaged the attention of physicists during some years. All measurements heretofore have been made by passing the beam through a prism and then by exposing a thermopile to the action of successive portions of the spectrum throughout its entire length. It has been found however that the prism exerts a selective action upon the rays which pass through it, depending upon the nature of the material from which it is made, and also by contracting the red and ultra red ends it gives false value to the measurements made upon them. It was proposed some time since to substitute a diffraction grating for the prism but the rays reflected from these were so feeble that the thermopile was found to be far too coarse an instrument to be sensitive to them. With the bolometer it has been possible however not only to detect their presence but to measure their intensity.

The instrument is constructed of two or more thin strips of metal arranged on the principle of the Wheatstone bridge. The strips are so arranged as to be under exactly the same conditions of temperature, etc., as regards surrounding objects, while it is possible to allow the rays of the spectrum to fall on one strip and shield the other. According to the law discovered by Siemens when the rays fall on the metal strip it becomes heated and its resistance to the passage of an electric current increases with the temperature. If now both strips are connected with a delicate galvanometer and a current passed through them before the experiment is made produces equilibrium, when one is exposed to the action of the rays, the resistance in it is increased and the needle is deflected. The amount of deflection measures the temperature of the strip. With this instrument a difference of $\frac{1}{10000}$ of a degree Centigrade produces a measurable deflection and a change of $\frac{1}{100,000}$ of a degree can be noted. The strips of metal usedare from $\frac{1}{2000}$ to $\frac{1}{12500}$ of an inch thick.

With this instrument Prof. Langley finds "that (contrary to the statements of our text books, and contrary, as I think, to most present scientific opinion) the great proportion of all solar heat received at the earth's surface does *not* apparently lie in the non-luminous part of the spectrum. Not only is the heat maximum in the luminous part, but the total sum of non-luminous heat (as far at least as our measures extend) is relatively small, the joint effects of the ultra red and ultra violet radiations, (so far as measured) not making up the sum of those in the visible portion. This is a result to me unexpected, but which I think may be relied on."

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MITTHEILUNGEN UBER GEGENSTANDE DES ARTILLERIE UND GENIE-WESENS. 1880, PART 5. The influence of the ground upon infantry fire. The cold punching of iron. Experiments with a 6.5 cm. sectional mountain howitzer.* Breaking up of two cast iron guns with dynamite.* The composition of several specimens of gun cotton by Capt. Philipp Hess.

According to recent reports the gun cotton produced by the Lenk-Abel process is in some measure unreliable. The attention which has recently been given in Austria to the utilization of its important properties as an explosive for war purposes has been extended also to the investigation of its differences of composition and has proved the existence of a great number of gun cottons. Several analyses have been made, the results of which are embodied in the table at the end of the paper together with data from other sources.

The processes employed in the analyses may be briefly described as follows. As it is essential that all calculations should be made upon the dry substance this is the first step in the process. The finely powdered cotton is enclosed in a glass tube through which a current of dry air at a temperature of 40°C is sent, until the weight is constant. Should it be desired to estimate the hygroscopic moisture it is simply necessary to weigh the tube and contents before drying. With compressed gun cotton the pulverization is essential as the hygroscopic condition will not be the same throughout the whole cartridge.

The ash is determined by the method given in this Mittheilungen (1879, N. S. 124) which consists in heating the dried gun cotton (about 5 grams) in a platinum evaporating dish with pure melted paraffine until the combustion is complete.

The soluble substances are obtained as an aqueous extract by digesting a weighed quantity of the cotton with water, and consist of alkaline carbonates. These may be better determined from the treatment of the ash with chlorhydric acid. The alkalies are dissolved and the remaining insoluble matter may all be estimated, without sensible error, as sand.

Another portion of about 5 grams of the dried and pulverized cotton is placed in a glass flask saturated with absolute alcohol and then ether is poured over the mass. After shaking thoroughly the flask is closed and left to digest at the ordinary temperature until the undissolved threads have gathered in flocks. The clear liquid is now filtered through a weighed linen filter and washed with the ether-alcohol mixture. The filter and residue are dried in a current of air at 40°C and weighed. The difference between the weight of the original cotton taken and of the residue gives the amount of mono and di-nitro cellulose. The residue contains the tri-nitro cellulose and unnitrified cotton, together with the portion of the ash which is insoluble in water.

* See No. 15, Proceedings Naval Institute.

To separate the trinitro cellulose from the unnitrified cotton an aliquot part of the residue from the previous operation is heated in a glass flask with an excess of a concentrated solution of sodic sulphide. The trinito cellulose is thus brought into solution while the unnitrified cotton is not acted upon. It is then filtered through a weighed linen filter, washed with distilled water until a drop no longer imparts a color to acetate of lead paper, then with dilute chlorhydric acid to remove a trace of sulphide of iron and finally with distilled water. The filter is then dried in air at 40° C. and weighed. The residue contains the unnitrified gun cotton together with the mineral matter insoluble in chlorhydric acid.

In the following table *a* and *b* are gun cottons from the Kruppamühle factory in Oberschlesien. Specimens *c* and *d* are from another continental factory. Specimen *e* is from Waltham Abbey, made in 1874. Specimen *f* is the substance known as tonite made at Faversham. Analyses *g* and *h* are by Muspratt with Abel's gun-cotton. Analysis *i* is by Champion and Pellet and is calculated on gun-cotton free from ash.

COMPOSITION OF SEVERAL SPECIMENS OF GUN-COTTON, MADE BY THE LENK-ABEL PROCESS.

Designation of Specimen.	Percentage in specimen of: Trinitro cellulose.	Mono and Di-nitro cellulose.	Cellulose.	Aqueous extract.	Sand.	ther substances in Ash.	Total.	Analyst.	Remarks.
a	88.60	5.51	3.30	1.64	0.37	0.17	99.59	Capt. Hess.	
b	89.10	5.57	3.28	1.40	0.33	0.69	100.37	Lt. Dolliak.	
c	80.33	9.44	8.40	0.25	0.06	1.56	100.04	Capt. Hess.	
d	80.57	9.20	8.41	0.26	0.05	1.60	100.09	Capt. Hess.	
e	85.53	6.45	3 57	2.43	0.22	1.86	100.06	Lieut. Dolliak.	
f	93.13	5.63	1.05	——	0.19		100.00	Capts. Hess and Schwab.	The aqueous extract contained only tonite.
g	81.50	12.00	5.00		0.5		99.50	Muspratt.	
h	82.50	12.00	4.00		0.5		99.50	Muspratt.	
i	93.00	6.00	1.00	——	——	——	100.00	Champion and Pellet.	

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places and of less important works; to engage in battle almost always successfully, with the southern iron-clads along the sea-coast and in hostile rivers; and finally to chase the confederate cruisers on all the seas of the globe: if we think, then, of so many operations, so complex and of such a varied nature accomplished by this fleet, we shall get an idea of the immense part it had to fill during the war of secession.

At the end of this work, we will show the influence such a struggle had upon the progress of Naval art. At present, let us be contented to render justice to the seamen who brought it to such a happy end. From the beginning of the war, we see them carry under the fire of the confederate forts, without hesitation, their old steamers and fragile gunboats of wood, or protected with inadequate armor. But it is to Admiral Farragut especially that honor redounds for showing, by more than one aid to the Union cause, what could be done with such a fleet hitherto regarded as useless. At New Orleans, Vicksburg, Port Hudson, and even at Mobile he did not fear with wooden corvettes and gun boats to brave a series of works behind which the Confederates believed themselves secure to defy the attacks of a formidable fleet. It is necessary to study in detail the engagements fought by this illustrious seaman to appreciate the great qualities of which by many circumstances he proved himself possessed: —his precaution before battle, his skilful foresight in manœuvre and remarkable energy in action! With him, how many other remarkable officers could we name: Admirals Porter, Davis, Foote, Goldsborough, Captain Worden, who commanded the Monitor at Hampton roads, Lieutenants Flusser and Roe,—who, the first dared to fight by ramming the iron-clad Albemarle with wooden vessels simply—Cushing, who destroyed this same vessel by means of a torpedo—many others still, as skilful as brave. The confederate navy too can cite with pride some names, for we should not forget under what unfavorable conditions its brave officers were obliged to fight. The hulls of the confederate vessels, rams or gun boats, were crudely constructed, with inadequate armor, with machinery continually subjected to damages, and with guns relatively less powerful. Yet with *matériel* less defective what might not have been expected of officers like Rear-Admiral Buchanan, who commanded successively the Virginia at Hampton Roads and the Tennessee at Mobile,—like the courageous Captain Montgomery, commanding the squadron destroyed at Memphis,—like the heroic Lieutenant Dixon, whose triumph in sinking the Housatonic was his shroud! In fine if the federal sailors had the honor of being the first to use turret vessels, it was their adversaries who inaugurated with the Manassas and the Virginia the ram, and who, guided by the counsel of the illustrious Maury, showed the power of torpedoes as offensive and defensive weapons. The destruction of the Housatonic preceded that of the Albemarle and about twenty federal vessels were sunk during the war by the stationary torpedoes of the Confederates."

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LIEUT. COMMANDER P. F. HARRINGTON, U. S. N., in the Chair.

THE COEFFICIENT OF SAFETY IN NAVIGATION.

BY PROF. W. A. ROGERS, OF CAMBRIDGE (U. S.) OBSERVATORY.

It is customary among engineers and architects, in making allowance for the strain to be borne by any part of a structure, to assign to the materials used a strength sufficient to withstand a strain much greater than that to which the structure is ever likely to be subjected. By a combination of theory and experiment it can be found, for example, what is the *breaking load* of a wooden or iron beam of given dimensions, and from the empirical law thus established we can ascertain approximately the breaking load for any beam of the same material and having the same form and dimensions; but in order to cover all possible differences which may exist among different beams, a coefficient of safety is either introduced into the formula representing the breaking load, or is applied to the result obtained from the formula. This coefficient should be large enough to cover not only the largest possible deviation between theory and experiment, but also to meet all unforeseen emergencies, such as time and age inevitably bring.

Passing now to the consideration of the term *coefficient of safety* as applied to navigation, it is our object to find the limits within which, under ordinary circumstances, a vessel can be located at sea,

and then to adduce some considerations which will enable us to form an intelligent judgment in regard to the *range of error* to which observations are liable. The quantity wanted is the average number of miles of error in latitude and longitude which we may fairly charge upon a single observation at sea under ordinary circumstances. We have then to find the coefficient by which this number must be multiplied in order to secure absolute safety, as far as safety depends upon human means and exertions. If we represent the average error by E, and the safety coefficient by P, then $E \times P$ should cover not only the range of error to which observations at sea are liable, but also those extreme cases in which a combination of causes acting in the same direction may produce errors of greater magnitude than the most prudent navigator would even suspect. We start with the average error E, in a given series of observations. It is obvious that the absolute error may be as small as the least value of the series and as large as the greatest value. A constant error may also be involved in every observation of the series, even when there are no indications of its existence. The total error therefore may be:

$$E \times P + \text{a constant.}$$

In this investigation the computed value of the coefficient P is obtained by dividing the difference between the greatest and the least values of a given series representing errors of observation by the average value.

Capt. Williams of the ill-fated Atlantic is represented by a reporter of the New York Tribune to have said that he knew the position of his ship within her length, at the time of his last observation, twelve hours before she became a wreck. If he really made that statement, no other evidence is needed of his utter unfitness for the position which he occupied. After twelve hours' run his error was twelve miles. Was that so large an error as to justify the charges with which the daily press teemed, that he had "blundered in his calculations"? In the court of investigation which followed the disaster, was the question how far it might have been allowable for him to have been in error, raised? Did the daily press raise this question? Was the question ever considered in any court of inquiry? Not as far as I can ascertain. Was this aspect of the question ever investigated at all upon any intelligent basis? If it has been, I have failed to find a record of it, after the most diligent search. In no one of

the forty-three volumes of the English Nautical Magazine, a standard authority, to which I am largely indebted in this discussion, can I find the question once raised, and I think there are few articles bearing upon the subject of wrecks which I have not consulted. In the British Admiralty laws on this subject, especially in the new code adopted in 1849, after the repeal of what is known as Huskinson's law, almost every aspect of the question is considered except this. There are regulations upon almost every conceivable point, from the constitution of courts of inquiry to the furnishing of proper lime-juice for seamen. In the Wreck Register, published annually by the British Board of Trade, to which I am largely indebted for data, not only the number, but the causes of wrecks are enumerated. A small number are attributed to the incapacity of masters, but even here there seems to have been so far no inquiry as to what constitutes incapacity in this respect. If it is a fact that navigators proceed upon the supposition that they can with certainty obtain their position by astronomical observations within one mile, to say nothing of three hundred feet, the wonder is, not that so many wrecks occur, but that more do not occur. I have said I could find no mention of this aspect of the question. Perhaps I ought to except two editorials on the loss of the City of Washington. The New York Times said: "It is believed that the captain of an ocean steamer, freighted with a priceless cargo of human life, should know at all times, in spite of fog and tempest, just where he is." To which the New York World replies, that "any one who believes such stuff as this is an idiot, and that the only way for him to find out anything about the Nova Scotia coast would be by taking command of a ship freighted, not with a priceless cargo of human life, but with a crew of cheap and congenial idiots, and required to know in spite of fog and tempest just where he was." One might almost say that the 19th century is behind the 18th in a proper appreciation of the importance of the true solution of this problem. As early as 1598, Spain offered a reward of 1000 crowns for the discovery of a correct method of finding the longitude at sea. The States of Holland, at an early date, offered a reward of 100,000 florins, and France a reward of 100,000 livres. In 1714 the British government offered a reward of £10,000 to any one who should discover a method of finding the longitude at sea within sixty miles, £15,000 within forty-five miles, and £20,000 if within thirty miles. This offer did much to awaken interest in the subject. Though we have long since passed the lowest limit then mentioned, thirty miles,

it is doubtful if any two navigators will agree as to what limit we have actually reached. The general testimony of sea-captains in answer to my inquiries upon this point, is that one mile is the ordinary limit within which the co-ordinates of a ship's place can be determined. A few placed the limit at half a mile. Only one man placed the limit at five miles. He had had an experience of thirty-six years, and was considered a man of excellent judgment. For myself, I have great respect for his judgment.

I now propose to show that this is not an idle inquiry. The number of steam and sailing vessels belonging to the United Kingdom of England, Ireland, and Scotland is about 25,000. The number belonging to the United States is at the present time about 22,000. These numbers vary from year to year with the conditions of trade and with the laws of supply and demand. A certain proportion are annually wrecked, either wholly or partially, the actual number for any given year varying to a certain extent with the total number of vessels, but being largely dependent upon the violence of the storms occurring during that year. But in a given series of years the average of the conditions of the latter class under which wrecks occur must be nearly the same, and the number of wrecks ought to be nearly proportional to the total number of vessels, under average conditions of carefulness in navigation. It is therefore essential to our investigation to inquire *whether the ratio of the number of wrecks to the total number of vessels in a given series of years is an increasing or a decreasing ratio.*

The following data are, for Great Britain, derived from the returns to the British Board of Trade, under the title of Wrecks and Casualties, and for the United States from the reports of the U. S. Life Saving Service. Inasmuch as the question of collisions does not necessarily come within the scope of the present investigation, the number of wrecks and casualties are given both including and excluding collisions.

Great Britain.

Year.	No. Vessels (Steam and Sailing).	Total Tonnage.	No. of Wrecks including Collisions.	No. of Collisions.	No. of Wrecks excluding Collisions.
1856	25335	4304460	1153	316	837
1857	26219	4491377	1143	277	866
1858	26658	4587893	1170	301	869
1859	26804	4591250	1416	349	1067
1860	26764	4586742	1379	298	1081
1861	27142	4735491	1494	323	1171
1862	27525	4860191	1488	338	1150
1863	27750	5251757	1664	331	1333
1864	27737	5542878	1390	351	1039
1865	27868	5666873	1656	354	1302
1866	28072	5692010	1860	422	1438
1867	27918	5670350	2090	414	1676
1868	27635	5698774	1747	379	1368
1869	26389	5634727	2114	461	1653
1870	25643	5617693	1502	361	1141
1871	25188	5622660	1575	351	1224
1872	25093	5681963	1958	409	1549
1873	24873	5736368	1803	381	1422

United States.

1873–4	.....	....	1060	...	....
1874–5	.....	....	1610	...	....
1875–6	22577	....	2097	576	1521
1876–7	22476	....	1935	521	1414
1877–8	21995	....	1816	545	1271
1878–9	21611	....	1953	568	1385

It is at once apparent from the returns for Great Britain that with a *decrease* in the number of vessels we have an *increase* in the number of wrecks and casualties. Comparing the data for the first half of the series with the data for the second half we have the following:

Limiting Dates.	Average No. of Vessels.	Average Tonnage.	Average No. of Wrecks including Collisions.	Average No. of Collisions.	Average No. of Wrecks excluding Collisions.
1856–64	26882	4772449	1366	320	1046
1865–73	26520	5669046	1812	393	1419

Decrease in the number of vessels, 1 per cent.
Increase in the total tonnage, 19 per cent.
Increase in the number of wrecks including collisions, 33 per cent.
Increase in the number of collisions, 23 per cent.
Increase in the number of wrecks excluding collisions, 36 per cent.

The percentage of decrease for the number of vessels should really be considerably greater than appears from the table, since previous to 1865 the enumeration was limited to vessels of eight tons, while after 1865 all vessels of three tons and upwards were placed upon the register.

In the returns for the United States, the numbers for 1873–4 and 1874–5 are undoubtedly too small, as no adequate means were employed for collecting the data till after the congressional act of 1874. For the four years for which we have reliable data, the average number of wrecks excluding collisions is 1398, which, in proportion to the number of vessels, is somewhat less than the number for Great Britain during the years 1865–73.

Comparing the number of collisions which occurred in Great Britain with the number which occurred in the United States we find:

In Great Britain the ratio to the number of vessels is as 1 to 67.

In the United States the ratio to the number of vessels is as 1 to 43.

Since in a large number of cases the average of all the causes, except carelessness, which produce collisions must be a constant, the modulus of carelessness as between Great Britain and the United States may be stated to be as nearly as 2 to 3 in favor of the United States.

These comparisons seem to justify a new discussion of the whole problem of wrecks and their causes. The arrangements for collecting data respecting wrecks, under the auspices of the British Board of Trade, have been constantly improved since their inauguration in 1855. In the United States the improvement in this respect since the organization of the Life Saving Service in 1871, and especially since the more complete organization in 1875, is signally marked. In both countries, especially in Great Britain, the rules for the examination of both inferior and superior officers are rigidly enforced. In no other countries are courts of inquiry upon disasters more surely held or more thoroughly conducted, and yet with all these precautions it is almost certain that the average number of wrecks in any given series of years will exceed those for the same number of preceding years, the number of vessels remaining the same. It is hardly probable that unknown or unsuspected elements enter into this problem. It is possible, however, that the limits of official investigation may be enlarged with great advantage.

I shall presently attempt to ascertain the ratio of wrecks which occur from preventable causes. If I were asked to name the one cause

which, next to positive negligence, produced the largest number of wrecks *of this class*, I should say, *over-confidence*. This excess of confidence is, in general, inversely proportional to the intelligence of the navigator. Of course, a successful sea-captain *must* rely upon his judgment; but the inevitable tendency of many years of service, with almost every possible form of experience, is to convince him that his judgment is rarely in error. Especially is this the case in too positive forecasts of the weather, in the accuracy of his observations for position at sea, and in the performance of his chronometer. Of course he places the utmost confidence in the accuracy of all data derived from the Nautical Almanac. I shall presently show that even here this confidence is not justified. In 1860, Professor Main, in his address before the Royal Astronomical Society, said, "Hansen's Tables (of the moon) are practically perfect for all the purposes of navigation, and the great nautical problem of finding the longitude at sea is now completely solved." Is it not possible that assertions like this inspire a confidence which may be the cause of more wrecks than has been hitherto supposed? Is it a fact that the problem is completely solved? I assert distinctly that it is not. I know of no more mischievous and misleading statement than this by Mr. Main, unless it be that of our own countryman, Lieut. Maury, on the performance of the chronometers used in the Grinnell Arctic Exploring Expedition. In a letter to the makers, he says, "The instruments have been subjected to the severest tests to which it is possible to subject instruments of such delicate construction, yet so exquisitely were they provided with adjustments and compensations for the very great extreme of temperature to which they were subjected, that one of them, No. 114, Loseby, after having suffered all sorts of exposure to which such instruments are liable in a polar winter, is returned with a change in its daily rate during seventeen months of only .03 s." (Signed) M. F. Maury.

This may be called a first-class recommendation, and this endorsement being good by inference for all of Mr. Loseby's chronometers, purchasers are led to suppose that they are as near perfection as human skill can make them. By reference to the report of the annual trial of chronometers at the Greenwich observatory it appears that while Loseby made some very excellent chronometers, he made also some very poor ones. I think I am safe in saying that this is the experience with the chronometers of every first-class maker.

Let us now see what is the actual state of the official inquiries into the causes of wrecks. By the Merchant's Shipping Act of 1854, it is assumed in the preliminary courts of inquiry, testimony which is held valid in Admiralty courts, that a vessel may be lost:

(*a*) By the act of God, *e. g.* being injured or destroyed by lightning, unavoidable perils of the sea, &c.

(*b*) By collision.

(*c*) By error of judgment, incompetency of master, or officers, or pilots.

(*d*) By bursting of boilers, breaking machinery, &c.

(*e*) By the removal of buoys, beacons, &c.

(*f*) By direct and wilful casting away.

(*g*) By inattention to necessary repairs.

(*h*) By defective charts.

(*i*) By not providing proper apparel and equipments for officers and crew.

(*j*) By improper loading or stowage.

(*k*) By neglect of regulations for preventing collisions.

(*l*) By employing a vessel in a trade for which she is unfit.

(*m*) By act of the Queen's enemies.

The nautical literature of this period is full of additional causes and remedies. The most important of these are:

(*n*) Failure to get the latitude.

(*o*) Failure to heave the lead.

(*p*) Unexpected deviation of compass.

One writer adds with a grain of truth, two other causes:

(*q*) A dead-and-alive set—no devil on board.

(*r*) Discord and dissension—the devil let loose.

An examination of the special and official inquiries into wrecks and casualties, and their causes, will show that the findings are based on one or more of these causes.

As an illustration, it appears from the Wreck Register for 1869 that there were during that year ninety-seven trials with the following results:

No. Cases		97
Acquittal from blame	39	
Censures	10	
Certificates cancelled, (drunkenness)	3	
Certificate suspended, 5 years	1	

Certificate suspended, 18 months	. . . .	2
" " 12 "	. . . . .	12
" " 9 "	. . . . .	2
" " 6 "	. . . . .	16
" " 3 "	. . . . .	4
" " 2 "	. . . . .	2
Left for decision of higher court	. . .	6
Total	. .	97

It is my purpose in this investigation to examine only those cases of wrecks which in a measure seem to have escaped attention in official investigations. They are—

I. Wrecks which occur from preventable causes.
II. Wrecks resulting directly or indirectly from over-insurance.
III. Wrecks caused by the deviation of the compass.
IV. Wrecks caused by errors of observations at sea.

In attempting to distinguish between the causes of wrecks, one is compelled to acknowledge at the outset that the statistics reveal certain facts which in the present state of our knowledge are very difficult to explain. Apparently the most feasible way of ascertaining what proportion of wrecks occur from preventable causes, is to account for those which occur from all other causes which can be clearly assigned, and after making a proper allowance for unknown causes, to place the balance in this class. But this cannot be safely done till further investigations are made with respect to certain facts which are revealed by the statistics already accumulated. These may be stated as follows:

(a) *The number of wrecks involving total loss is nearly proportional to the total number of vessels, while the number of wrecks involving partial loss shows a steady increase from year to year.* This will appear from the following table.

WRECKS OTHER THAN COLLISIONS IN THE UNITED KINGDOM.

Year.	Total Loss.	Partial Loss.	Year.	Total Loss.	Partial Loss.
1856	368	469	1867	356	1020
1857	384	482	1868	527	841
1858	351	515	1869	606	1047
1859	527	540	1870	411	730
1860	476	605	1871	398	826
1861	513	658	1872	439	1110
1862	455	695	Jan. to June 1873	212	522
1863	503	830	June to June 1873–4	346	1076
1864	386	653			
1866	470	832			

(b) *The increase in the number of wrecks outside of the "At Home" limits is proportionately much larger than within those limits.* The "At Home" limits "embraces the cases which happen in waters within 10 miles from the shores of the United Kingdom; in waters within any bays or estuaries; in waters around any outlying sand-banks which are dry at low water; in the seas between Great Britain and Ireland; and between Orkney and Shetland and Western Islands and the mainland of Scotland." Returns of this class began with 1867. I extract from the returns for 1873–4 the following significant numbers for British vessels only.

						Jan. to June.	June to June.
Total No. of wrecks, casualties and collisions.	1867	1868	1869	1870	1871	1872	1873	1873–4
	935	935	961	1208	1754	2415	1156	3094

These numbers include vessels belonging to the British possessions, but the total numbers belonging to this class follow nearly the same law as those which are referred to the United Kingdom; *i. e.*, there is a steady *increase* till about 1866, and after that a steady *decrease* till 1874.

(c) *Over one-half of the total number of wrecks occur when the wind blows less than a fresh gale, or "when a ship if properly found, manned and navigated can keep the sea with safety."* The following table furnishes conclusive evidence on this point. It is taken from the Wreck Register for 1875.

Wrecks Classified According to the Force of the Wind.

1864–65	1865–66	1866–67	1867–68	1868–69	1869–70	1870–71	1871–72	1872–73	1873–74	Total.	
23	19	12	15	16	25	33	31	26	29	229	Calm.
18	26	27	22	31	32	57	42	57	48	360	Light air.
92	95	65	61	93	115	115	109	136	129	1010	Light breeze.
23	19	31	35	25	37	50	52	65	68	405	Gentle breeze.
149	150	176	150	157	162	161	198	175	211	1689	Moderate breeze
210	228	228	199	185	208	180	213	248	234	2131	Fresh breeze.
175	187	230	196	250	205	234	255	312	283	2329	Strong breeze.
46	52	97	59	78	50	80	95	197	165	919	Moderate gale.
48	77	88	120	54	61	87	96	240	149	1020	Fresh gale.
414	605	617	417	629	515	336	234	348	205	4320	Strong gale.
211	157	204	310	139	186	182	126	246	160	1921	Whole gale.
37	46	28	62	29	34	29	21	56	31	373	Storm.
49	173	61	72	89	93	38	26	38	27	666	Hurricane.
9	2	1	2	—	—	5	8	8	22	57	Variable.
59	73	72	77	97	91	61	15	52	42	639	Unknown.

(d) *The number of wrecks is proportionately larger for new vessels than for those which have reached the average age of service.*

Data:

FOR GREAT BRITAIN.

Age, Limiting Years.	1865	1866	1867	1868	1869	1870	1871	1872	Jan. to June, 1873	1873–4	Total.
0– 3	151	277	209	176	198	130	155	211	94	182	1733
3– 7	260	280	322	297	406	307	302	374	209	354	3111
8–10	203	221	238	152	218	148	163	239	127	254	1963
11–14	173	198	262	268	308	218	198	242	136	227	2230
15–20	269	289	306	270	314	246	243	322	170	318	2747
21–30	352	419	441	383	436	272	311	344	163	297	3418
31–40	145	174	209	167	229	143	184	212	118	221	1802
41–50	84	87	118	100	112	63	81	86	61	81	873
51–60	51	53	60	35	53	49	44	47	19	41	452
61–70	20	25	36	28	18	20	19	24	13	13	216
71–80	9	13	9	9	9	4	6	17	8	6	90
81–90	5	5	3	8	5	5	8	4	2	5	50
91–100	1	2	1	..	2	..	..	5	..	2	13
101+	1	..	1	..	..	1	3	2	2	2	12
Unknown.	288	296	298	238	286	259	210	252	84	188	2399

FOR THE UNITED STATES.

Age, Limiting Years.	1875–76	1876–77	1877–78	1878–79	Total.
0– 3	341	246	159	128	874
3– 7	318	276	368	305	1267
7–10	357	227	278	287	1149
10–14	275	243	324	307	1149
14–20	243	173	197	262	875
20–25	160	113	164	161	598
25–30	103	83	99	112	397
30–35	17	20	32	44	113
35–40	26	21	20	18	85
40–45	8	12	8	14	42
45–50	4	3	6	3	16
50+	7	1	4	7	19
Unknown	164	107	153	94	518

(e) *The number of wrecks is to a large extent dependent on the character of the cargoes of the vessels wrecked.*

Data:

FOR GREAT BRITAIN.

	Ballast [not Colliers].	Coal.	Colliers in ballast.	Fishing Smacks.	Grain and Provisions.	General Mdse.	Lumber.	Stone and Bricks.	All others.	Total.
1864–65	191	550	131	101	119	78	88	105	550	1913
1865–66	244	701	119	109	178	77	115	136	657	2336
1866–67	234	713	179	117	158	82	94	153	640	2370
1867–68	229	617	165	173	120	82	84	137	563	2170
1868–69	252	693	130	140	117	103	72	161	668	2306
1869–70	247	559	160	124	145	114	116	164	597	2226
1870–71	202	541	96	91	139	77	89	125	644	2004
1871–72	218	524	104	126	105	88	52	101	572	1890
1872–73	278	788	100	100	244	116	168	166	732	2692
1873–74	256	539	67	165	131	110	161	175	587	2191
Means..........	235	623	125	126	146	93	98	143	621	2210

FOR THE UNITED STATES.

1875–76	474	273	...	148	114	125	178	57	654	2023
1876–77	426	248	...	74	61	129	224	28	697	1887
1877–78	413	244	...	64	117	102	200	38	643	1821
1878–79	474	273	...	38	103	125	466	23	521	2023
Means..........	447	259	...	81	99	120	267	36	629	1938

After making a liberal allowance for the larger number of vessels engaged in certain kinds of trade, it still remains that there is an excessive number of wrecks corresponding to certain classes of cargoes. I do not pretend to offer any explanation of the questions raised by a study of these tables. I can only call attention to the need of a careful study of the hidden causes of the anomalies which they reveal.

In attempting to ascertain the ratio of wrecks which occur from preventable causes, I am limited to two sources of information; these are:

(*a*) The numerical data furnished by the Wreck Register for Great Britain, and by the reports of the Life Saving Service for the United States.

(*b*) The comparison of the findings of the courts of inquiry upon the causes of wrecks, casualties and collisions, ordered by the British Board of Trade or reported to this Board. Both in Great Britain and in the United States an attempt is made to distinguish the causes of all the wrecks which occur. In the British Wreck Register these causes are grouped in four classes as follows:

Class I.

1. Foundering.
2. Driving or running on a sand or lee shore.
3. Parting cables.
4. Dragging anchors.
5. Damage to hull or rudder, or loss of masts, yards, sails, &c.
6. Shifting of cargo or ballast.
7. Missing stays.
8. Failing to make harbor, or stranding whilst entering.
9. Capsizing.

Class II.

1. Error, neglect or incompetency of master or mate.
2. Error, neglect or incompetency of pilots.
3. Improper stowage.
4. Not heaving lead.

Class III.

1. Unseaworthiness.
2. Overloading.
3. Defective charts, insufficient manning, unsound gear or equipments, imperfect repairs, or defective construction.
4. Local attraction and defects of compasses.

Class IV.

1. Thick and foggy weather.
2. Heavy seas.
3. Strong currents and light winds.
4. Want of lights or buoys on coasts and shoals.
5. Want of pilot.
6. Want of power in steam tugs, or defective tow ropes.
7. Striking on sunken wreck, &c.
8. Spontaneous combustion.
9. Fire or lightning.
10. Damage to boilers or machinery.
11. Accident.
12. Combination of causes.

In the reports of the Life Saving Service the causes are also grouped under four classes, but the arrangement is somewhat different from that given above.

In 1877, the two causes, "damage to machinery," and "explosion of boiler, bursting of steam pipes, etc.," were separated from Class IV and were grouped in a class by themselves. In this investigation the original grouping has been retained.

These classes are:

Class I.

1. Foundered.
2. Stranded.
3. Sprung a leak.
4. Capsized.
5. Waterlogged.
6. Damage to hull, rigging, rudder, &c.
7. Struck by lightning.
8. Machinery disabled.
9. Miscellaneous.

Class II.

1. Error in judgment.
2. Error of pilot.
3. Neglect of master.
4. Ignorance.
5. Carelessness.

Class III.

1. Defective instruments.
2. Defective hull, rigging, &c.

Class IV.

1. Adverse currents.
2. Heavy sea.
3. Accidental.
4. Fire.
5. Never heard from.
6. Thick and foggy weather.
7. Misstayed.
8. Sprung a leak.
9. Becalmed.
10. Parted chains, &c.
11. Struck bridges, piers, &c.
12. Waterlogged.
13. Explosion.
14. Absence of proper lights.
15. Miscellaneous.
16. Ice.
17. Machinery disabled.
18. High wind.
19. Darkness.
20. Tides.
21. Unknown.

Under the subdivisions given above we have the following data:

FOR GREAT BRITAIN.

WRECKS AND CASUALTIES OTHER THAN COLLISIONS FOR 10 YEARS.

Year.	Wrecks resulting in Total Loss arising from					Casualties resulting in Partial Damage, arising from					Total.
	Class I.	Class II.	Class III.	Class IV.	Unknown.	Class I.	Class II.	Class III.	Class IV.	Unknown.	
1865–6	320	120	62	64	19	574	127	47	143	11	1487
1866–7	340	121	74	72	15	538	120	65	161	10	1516
1867–8	269	85	55	87	20	571	130	70	134	6	1427
1868–9	276	94	95	96	17	470	151	84	160	8	1451
1869–70	253	66	56	89	36	557	134	65	150	6	1412
1870–1	203	89	58	97	26	375	159	102	176	8	1293
1871–2	72	104	43	78	13	341	199	144	158	5	1157
1872–3	185	95	52	97	67	632	223	133	244	4	1732
1873–4	128	93	30	53	42	525	180	91	251	29	1422
1874–5*	177	84	33	75	42	393† 906‡	182 234	129 59	240 325	37 15	2931
Total for 10 Years	2223	1509		1105		5882	2828		2281		15828

* In this year the partial damage is subdivided into † serious and ‡ minor casualties.

FOR THE UNITED STATES.

Year.	Class I.	Class II.	Class III.	Class IV.
1865–6	804	82	35	524
1866–7	706	50	33	543
1867–8	940	20	55	261
1868–9	990	18	74	336
Means	860	42	49	416

From these figures it is impossible to draw other than very general conclusions. Since the causes enumerated in Class IV are about equally divided between those which may be classed as preventable and those which are non-preventable, we may with tolerable confidence compare Classes I and II.

It appears therefore that for the total number of wrecks excluding collisions, 45 per cent. are due to preventable causes.

For the United States I can offer no explanation of the extremely small ratio of Class II to Class I. The omission of the cause "failure to heave the lead," suggests that the data is not altogether reliable. That this cause cannot be safely omitted will appear from the fact that between 1856 and 1872, out of less than five hundred cases of punishment imposed for default by English courts of inquiry, 102 were for "neglect of lead."

In 1865 the British Board of Trade began the yearly publication of a resumé of the findings of the courts of inquiry instituted for ascertaining the causes of wrecks, and for the punishment of those convicted of default in navigation, by reprimand, by suspension or cancellation of certificates of competency, and even by fines and imprisonments. In the Wreck Register for 1873 there is a brief resumé of all the trials which occurred between 1856 and 1873. The total number is 1163. I have examined each of these findings, and selected those in which there is a clear acquittal from blame, care being taken to exclude all cases in which there is even an admonition, although the certificate was returned. From this examination it appears that there were 384 cases out of the total number 1163 in which the casualties occurred from causes clearly beyond the control of the master or mate.

From an examination of the findings between 1867 and 1874 I find the following results:

Year.	No. of Acquittals.	Total No. of trials.	Year.	No. of Acquittals.	Total No. of trials.
1865	29	46	1870	86	251
1866	46	81	1871	44	130
1867	9	30	1872	70	169
1868	21	47	1873	38	102
1869	39	97	1874	122	314

We have here 504 clear acquittals in 1267 trials, giving a ratio not far different from that obtained from the findings between 1856 and 1872, in which as nearly as can be made out the cases tried were different from those recorded in the annual volumes.

It is not to be understood that the findings in the remaining 763 trials are all for default of the master or mate, inasmuch as the inquiries often extended to their conduct *after* the casualties occurred.

In the Register for 1876 there is a remarkable increase of the number of trials reported, covering the years 1874–5 and 1875–6. I copy the summary given:

Cancellation of certificates	11
Suspension of certificates	204
Certificates returned	178
Unseaworthiness	13
Overloading, bad stowage	18
Defects in equipments	7
Stress of weather	128
Fire or other accidents	68
Cause not stated	64
Total . . .	691

In both of these investigations there is one class of wrecks for which no cause can be safely assigned, viz. that involving vessels which were never heard from after sailing, for in these cases there are no records either of efforts made or of sufferings endured. The reports with respect to this class of wrecks are very defective. In the Wreck Register for 1874 there is for the first time a separate list of British ships not heard from after sailing. Of this class there were 83 in 1873–4, 137 in 1874–5, and 101 in 1875–6. The total number reported in the reports of the Life Saving Service for the years 1875–6 to 1878–9 is 59. It is probable that these numbers are somewhat too small, for according to the Insurance Reports of Great Britain there were between 1864 and 1869 (inclusive ?) 10,588 wrecks of which the end of 846 is unknown.

There is also another class of wrecks which may be much larger than is usually supposed, viz. wrecks for which it is exceedingly difficult to determine the true cause. In any given investigation it is imperative that the inquiry shall be extended beyond the immediate cause. A wreck may apparently occur by the act of God and yet be due to the previous folly of man. Take the case of the barque Providence, which sprung a leak in the Baltic on a voyage to Dantzic. After the crew had arrived at the last point of exhaustion in their efforts to stop the leak, it suddenly stopped, and the vessel arrived safely at her destination. After the discharge of the cargo it was found that the leak had been caused by the giving way of a knot in a bottom plank, and that it had been stopped by a dead fish, which acted as a plug. If the vessel had been lost there would have been no evidence of the cause. As it turned out, the builder had to suffer the penalty for what might have been charged with apparent reason as an act of

God. One can hardly tell where to place the case of the steamship L'Amerique of the French line between New York and Havre. She sprang a leak, and after being abandoned, was picked up and manned by a British crew, when it was found that through the ignorance of the engineer the donkey engine had been pumping water *into* instead of out of the ship.

Combining the results obtained from these independent inquiries, the general conclusion is reached that about one-half of all the wrecks which occur may be due to preventable causes.

Under the second head a complete and satisfactory investigation is wellnigh impossible. That the whole question of insurance in connection with wrecks involves more or less of fraud is evident from the following extract of a speech before the United Service Institution by Admiral Halstead, Secretary of Lloyds. He said: "The remedy for shipwrecks—what is it? I do not pretend for one instant to be able to provide a remedy, and I do not know anybody who can undertake to say what is a remedy; but I will tell you this: if I could go on the Stock exchange to-morrow morning, and by holding up my hand put a stop to all shipwrecks upon the coast, it would be a question how I could get safe with life off that Exchange. When I put that question to him (Lloyd) he said, '*It is perfectly true, you would stop our bread.*'"

As for definite data, it is only possible from the nature of the case to obtain a little here and a little there. The cases of the Dryad and the Harlequin, in 1837, show that in those days at least the question of insurance had a very definite bearing upon the question of wrecks.

In 1866, Thomas Berwick was connected as an accessory in the destruction of ships owned by Thos. Berwick & Son. On his trial he confessed to having destroyed no less than nine vessels in the course of twenty years.

In 1867 there were in the Baltic 215 British vessels, and in 1868, 220 Swedish. The British vessels were largely insured, while on the Swedish vessels there was very little, if any insurance. Of these numbers, 17 British and 3 Swedish were lost. From 1857 to 1867 the ratio was 10 British to 3 Swedish. It is hardly probable that this disparity of numbers can be accounted for by the superior skill of the Swedish navigators.

The data which I shall now offer will need to be taken with a large allowance for imperfect returns, but the near approach of the total insurance to the total value of the vessels and cargoes lost, and espe-

cially the large excess of the insurance over the actual loss, proves either that the business of insurance involves enormous profits, or that it involves extensive fraud on the part of those who insure. As before, the returns are derived from the Wreck Register for 1875, and from the annual reports of the Life Saving Service between 1875–6 and 1878–9.

For Great Britain.

Vessels.

Year.	Total No. Insured.	Total Am't of Insurance	No. rp'd not Insur'd.	Unknown.	No. on which loss was report'd	Estimated loss.	Av'g am't of Ins. on each vessel.	Aver'ge loss on each vessel.
1865	811	£1,102,070	298	903	1331	£1,060,568	£1359	£797
1866	894	1,250,262	416	979	1854	1,018,000	1399	549
1867	1072	1,380,912	481	960	2067	1,282,888	1288	621
1868	906	1,195,025	456	769	1727	899,604	1317	522
1869	1114	1,758,350	478	1002	2102	1,240.535	1578	590
1870	711	1,474,414	356	798	1483	964,317	2074	650
1871	800	1,623,099	419	708	1565	1,141,845	2029	730
1872	1009	2,092,830	477	895	1950	1,165,466	2074	598
Jan–Jun 1873	500	1,265,743	227	479	1006	582,489	2531	579
1873–4	847	1,930,907	502	842	1842	899,201	2280	488
1874–5	1597	4,280,813	893	1769	3347	1,369,709	2681	409

Cargoes.

Year.	Total No. Insured.	Total Am't of Insurance	No. rp'd not Insur'd.	Unknown.	No. on which loss was report'd	Estimated loss.	Av'g am't of Ins. on each vessel.	Aver'ge loss on each vessel.
1865	108	£115,905	135	1312	468	£500,467	£1073	£1069
1866	160	376,869	167	1512	590	453,640	2355	769
1867	212	300,117	228	1413	637	625,602	1416	982
1868	183	299,985	202	1276	529	363,697	1639	688
1869	284	487,506	226	1498	642	345,843	1717	539
1870	182	482,348	213	1135	486	414,510	2650	853
1871	201	703,262	257	1086	475	372,772	3499	785
1872	282	476,448	363	1374	536	428,402	1690	799
Jan–Jun 1873	141	248,282	114	723	284	296,667	1761	1045
1873–4	250	324,806	226	1227	406	289,096	1299	712
1874–5	311	807,200	467	2380	495	334,054	2595	675

For the United States.

Vessels.

Year.	Total No.	Total Value.	Total No.	Total Loss.	Total No.	Total Am't Insured.	Average value of each vessel.	Avg loss on each vessel.	Average Ins. on each vessel.
1875-6	1800	$33,839,675	1788	$7,025,192	807	$11,677,106	$18,000	$3929	$14,470
1876-7	1771	35,973,839	1709	8,834,202	782	10,258,611	20,313	5169	13,118
1877-8	1724	29,195,845	1640	6,963,084	748	8,681,180	16,936	4246	11,606
1878-9	1853	29,450,662	1749	5,899,159	733	7,339,011	15,893	3373	10,012

Cargoes.

Year.	Total No.	Total Value.	Total No.	Total Loss.	Total No.	Total Am't Insured.	Average value of each vessel.	Avg loss on each vessel.	Average Ins. on each vessel.
1875-6	1307	$17,333,636	586	$2,687,228	487	$ 8,589,516	$13,262	$4586	$17,638
1876-7	1283	21,230,636	612	4,548,958	598	11,882,253	16,548	7433	19,870
1877-8	1276	18,738,387	621	3,979,806	562	9,678,110	14,685	6409	17,221
1878-9	1343	16,890,305	630	4,284,836	563	7,751,431	12,577	6801	13,768

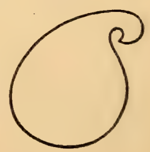
Under the third heading my investigations are far from complete or satisfactory, on account of the difficulty of obtaining reliable data. The compass problem is an intricate one, and has never been fully solved, though the researches of Flinders, Barlow, Scoresby, Airy, and Harkness have done much to convert great uncertainty into tolerable certainty. The discovery of the deviation of the compass is undoubtedly due to Columbus, though the claim is sometimes put forward in behalf of one Peter Adsiger, based on a manuscript deposited in the University of Leyden. But Humboldt has shown that this claim is a spurious one. The first observations on the variation were by Bond, in 1668. But the variation is a very irregular one. There are both yearly, monthly, and diurnal inequalities, the diurnal variation being discovered by Graham in 1722. (The dip of the needle is said to have been discovered by Robert Norman in 1576.) The following short table of variations at Greenwich will illustrate both their magnitude and their irregularity.

Year.	Mean variation Greenwich.	Range during year.
1865	20° 32′ 43″	3′
1866	20 27 47	11
1867	20 20 17	7
1868	20 13 14	6
1869	... ...	0

As an illustration of the monthly irregularity of variation, I give the Greenwich record for the first six months of 1841:

Month.	Variation.	Change from one month to next.
Jan.	23° 11′ 46″	+ 5′ 50″
Feb.	17 36	+ 1 42
Mar.	19 18	— 7 30
April	11 48	+ 5 54
May	17 42	— 1 24
June	16 18	

Here we have variations between different months amounting to nearly one-fourth of a degree. But the fluctuations of a single day are often more than for a whole month. These diurnal fluctuations are well illustrated by the following curve taken from the Greenwich observations of 1869.



The variation for long periods is well illustrated by comparing Halley's Chart for 1700 with modern charts. But the complexity of the problem does not stop here.

The tendency of the present time is to build iron ships, and all ships now have more or less iron in their construction. These ships become to a greater or less degree themselves great magnets. In wholly iron ships the uncorrected deviation of the needle often amounts to 50°, thus rendering it wholly useless. Captain Flinders in his voyage to Australia in 1811 was the first to make an intelligent discussion of this subject. The result of his investigations may be stated as follows:

I. A compass gives different bearings of the same object when placed in different parts of the ship.

II. When the ship's head is on the magnetic meridian there is no effect from local attraction, showing that the various masses of iron on board act in unison with the earth's magnetism.

III. When the ship's head is east or west the effect of local attraction is the greatest, and that at intermediate points the deviation varies as the sine of the angular distance between the magnetic meridian and the bearing of the ship's head.

IV. The maximum variation is different in different parts of the world, varying as the distance from the magnetic equator.

The polar expeditions of 1818 fully confirmed Flinders' experiments. Before reaching Greenland the compass of the Alexandria differed from that of the Isabella 11°, and the same compasses gave results differing 11° when placed in different parts of the ship. As the vessels passed up Davis straits all the compasses became sluggish. In Sir Edward Parry's passage through Barrow strait his compasses became totally useless. The admiralty law in regard to swinging for the variation of the compass is a very clear statement of the case. It reads as follows:

"As the deviation or error of the compass caused by local attraction of the ship becomes changed in amount by any change in the ship's geographical position, and may be entirely reversed in its direction by the ship's proceeding from the northern to the southern hemisphere, it is to be invariably tested by azimuth and amplitude observations at sea, and the ship is to be swung for ascertaining the change of error on arrival at a foreign station, and also once each year, and the same is to be inserted in the log-book and sent to the Admiralty with the quarterly return for December."

The next important discovery in this connection was by Barlow, who found that all the influence of iron bodies exerted on the compass resides on the surface. This discovery paved the way for Airy's method of correcting compasses, which is by swinging the ship in

the usual way, and then correcting the local attraction of the ship by means of permanent magnets of soft iron conveniently placed with respect to the compass. But the most important discovery was made by Dr. Scoresby. He found that every iron ship is itself a magnet, and that it gets its magnetism while building by the inductive magnetism of the earth, the poles of the ship's magnetism depending on the position of the building-yard and the direction of the keel in construction. Dr. Scoresby made the voyage of the world in the Royal Charter to test his theory, found by induction, and found it fully confirmed. Before starting his compasses were corrected by Airy's plan. On arriving at Melbourne it was found that a complete inversion of the ship's magnetic polarity had taken place. Every stanchion, every standard, every davit, every mass of iron about the deck had in its upper surfaces acquired a northern instead of a southern polarity, and the starboard compass had lost nearly one-half of its original errors. On returning to the place of starting in the northern hemisphere, and swinging the ship, it was found that a re-inversion had taken place; but the compasses did not quite return to their original deviations, but retained a fraction of their errors. It has since been found that these changes are much greater in steam than in sailing vessels, as shown by observations on board the Vulcan (steam) and the Pandora (sailing).

In 1852–3 Dr. Scoresby, in a paper before the British Association, showed that there is a sensible difference in the deviation before and after steam is up. It is said that the compasses of a steam vessel when light and running before the wind with a high sea are practically useless.

Within a few years the effect of the heel of a ship on the deviation of the compass has been pretty fully investigated. In general it is found that when a ship's head is nearly E or W there is no sensible effect from heeling, that when it is N or S the effect is greatest, and that the marked end of the needle is attracted to the raised side of the ship in north latitudes, and *vice versa* in south latitudes. In iron ships 1° of heel produces from 1° to 2° variation of the compass, generally about 1°. In a voyage of the City of Sydney, iron, 1100 tons, the deviation amounted to 1½° for every degree of heel. This deviation may be almost wholly prevented by the use of elevated compasses.

More recent experience has shown that the magnetism of an iron ship does not attain its normal condition till some twelve months

after launching, and that for some time after the variation is very irregular. In the Great Eastern, a fixed compass changed its deviation nearly three points in the first nine months of service. The observations of Professor Harkness on board a monitor seem to be conclusive on this point. It is apparent from this brief review that even with the utmost caution, ships may be misled by unknown variations, and yet the London Compass Committee as late as 1869 declare that very few ships are lost from this cause. What shall be said of ships that are never swung and whose masters know nothing of the laws of variation? The loss of the City of Washington is the best refutation of this statement. One of the most intelligent captains I ever met, a man who has commanded vessels for thirty-six years, and who has been to almost every great port on the surface of the globe, told me he had never swung his ship and that he had never seen a ship swung.

The opinion of the London committee was probably founded on the small number of disasters arising from errors of the compass reported in the annual returns. Between 1865 and 1874–5 only 34 cases are set down as due to this cause, while in the findings of the courts of inquiry between 1856 and 1872 there are only 21 cases of this class. In the U. S. Reports there are recorded 20 cases between 1875–6 and 1878–9, but here the distinction is not always made between "error of compass" and "error of chronometer."

That other competent authorities hold to a view radically different from that expressed by the London committee will appear from the correspondence between the Royal Society and the Board of Trade, printed in the Shipping Returns for 1865 (vol. LXV, 1866). The correspondence opens with the following letter:

ROYAL SOCIETY TO THE PRESIDENT OF THE BOARD OF TRADE.

THE ROYAL SOCIETY, BURLINGTON HOUSE, 25 May, 1865.

Sir:—The attention of the Fellows of the Royal Society has been recently directed to the very great increase which has taken place in the employment of iron in the construction and equipment of ships, and the consequent augmentation of the embarrassments occasioned in their navigation by the action of the ship's magnetism on their compasses.

The inconveniences which have already made themselves felt in the ships of the mercantile marine, and which threaten to be productive of very serious loss of life and property, unless remedial measures be adopted similar to those which have proved so advantageous to the ships of Her Majesty's navy, have induced the President and Council of the Royal Society, after much consideration, to

venture on the step of calling your attention, as presiding over the Department of Trade, to a subject which they believe to be of pressing importance.

In this view, the accompanying memorandum has been prepared, stating, as briefly as may be, the particulars which they are desirous of bringing under your consideration, in the belief that the time has fully arrived when measures of a more stringent and effectual character are required in the direction which has been already taken by Her Majesty's government in such legislative enactments as those contained in the "Merchant Shipping Act, 1854," adverted to in the accompanying memorandum.

I have only to add, that it would afford the President and Council great satisfaction if they could be of any further assistance in a matter which they believe to be of so much importance.

I have, &c.,

(Signed) EDWARD SABINE,
President of the Royal Society.

In the memorandum referred to, attention is called—

1. To the great increase in the number of iron ships, as well as in the amount of iron used in the construction of such ships.

2. To the losses of iron ships.

3. To the advances which have been made in, and the present state of the science of the deviation of the compass.

Also, the attention of the Board of Trade is drawn to the proposition to secure under competent authority—

(*a*) The correction of the compass in particular ships.

(*b*) The advancement of the science of the deviation of the compass.

(*c*) The education of masters and mates.

The reply of the Board of Trade to this communication contains a large amount of useful information, but fails, it seems to me, to grasp the vital point at issue, viz. the application to the mercantile marine of the system which has proved eminently satisfactory in the Royal navy.

The correspondence on the part of the Royal Society closes with the following communication:

THE ROYAL SOCIETY TO BOARD OF TRADE.

BURLINGTON HOUSE, 2d November, 1865.

Sir:—I have now laid before the Council of the Royal Society, your letter of the 25th of July, referring to the adjustment of the compasses of iron ships, and a copy of my letter of the 28th of August, acknowledging its receipt and adverting to the inquiry you had made as to the preparation of a "manual" on the

subject, together with your subsequent letter of 23d October having reference to the same inquiry.

The President and Council are much disappointed by learning that the Board of Trade are not prepared to give effect to the recommendation that the system which has been found to work so successfully in the Royal navy, of combining official and competent superintendence with a proper code of instruction, should be extended to the mercantile marine. They consider such superintendence to be essential, not only to the general introduction of a good and efficient mode of compass correction into the mercantile marine, but even to the discharge of the duties having respect to the adjustment of the compasses of sea-going passenger steamers, with which the Board of Trade is already charged by the legislature.

In the memorandum accompanying my letter of the 25th of May it was stated that many recent losses of iron steamers have taken place, in which it is probable that compass errors have occasioned the loss. The President and Council think it right to call the attention of the Board of Trade to the serious responsibility they incur in cases of loss of life and property arising from the want of a proper system of compass adjustment, by declining to take the course which is pointed out by the concurrent opinion of all competent advisers, as not only the best, but the only method of securing the introduction of such a system. They cannot but look forward to a time when the necessity of a proper supervision will be forced on the executive by public feeling, excited by some disastrous loss of human life traceable to the want of such superintendence.

The question is one of such vital importance that they desire to submit to the consideration of the Board of Trade the accompanying memorandum, replying in some detail to passages in your letter of 25th July.

I have, &c.,

(Signed) EDWARD SABINE,

President of the Royal Society.

As far as I can learn the compass problem still remains in the unsatisfactory state indicated by this correspondence.

[*To be continued.*]

NAVAL INSTITUTE—NEW YORK BRANCH.

June 10, 1881.

Lieut. F. Hanford, U. S. N., in the Chair.

MAGAZINE SMALL ARMS.

By Lieut. W. W. Kimball, U. S. N.

Magazine small arms are those shoulder pieces and pistols whose systems of construction enable them to fire several successive rounds without reloading. They are divided into two general classes, *revolvers* and *repeaters*, the former firing their charges from several chambers from which, till the successive discharges take place, the cartridges are not moved; the latter firing from a single chamber into which, by the mechanism of the piece, the several cartridges are successively loaded, from an attached magazine.

It might be supposed that the desirability of firing several charges without reloading would have presented itself to the users of fire-arms at an early date; and, as a matter of fact, we find that an arm possessing this feature was produced in the century following that in which Friar Schwartz's famous mortar-pestle took its unexpected flight into the air at Mayence. A specimen of these 15th century shoulder piece revolvers is now in the armory of the Tower of London. It consists of a cylindrical breech piece revolving upon an arbor welded to the barrel and parallel with its axis; the whole fitted to a stock and held in place by a traverse pin; notches in a flange at the fore end of the cylinder receive the end of a spring fixed to the stock and extending across the breech, the function of the spring being to lock the cylinder when a chamber is brought up on line with the barrel. Each chamber is provided with a priming pan having a swing cover which, before firing, requires to be pushed aside by the

finger in order to present the priming powder to the lighted match. Repetition of fire is effected by throwing back the match holder and turning the breech by hand to bring up another loaded chamber. The fittings and mountings of this gun, very similar to which are two eight chambered revolvers in the Musée d'Artillerie at Paris, indicate an early Eastern origin.

Another match-lock magazine arm, brought from India by Lord William Bentinck, closely resembles in principle the one just described, but the workmanship is superior and the ornamentation ornate. The breech cylinder has five chambers, each with priming pan and swing cover. The arbor is attached to the barrel, and at the breech where it abuts on the cylinder the barrel is enlarged to correspond with the diameter of the cylinder, to which it forms a kind of shield. The thinness of the metal of the barrels and the extreme length of the chambers in all these specimens would indicate that they were used in the days of powder dust, before the comprehension of the utility of granulation.

The 16th century has its magazine gun representative in the Tower of London armory, in the shape of a pyrites wheel-lock, shoulder piece revolver. It has one priming pan common to all the six chambers of the cylinder; the pan is fitted with a sliding cover, and is so arranged that the serrated edge of the vertical wheel may project into it, and consequently into the priming powder; to this wheel a rapid motion is given by means of a trigger spring acting upon a link lever attached to the arbor of the wheel, the teeth of which striking upon the pyrites create the sparks that ignite the priming; the fire is then communicated laterally to a train of powder about 2.5″ long, before it reaches the charge in the cylinder. A repetition of fire is produced by rotating the cylinder by hand, repriming the pan and train channel, and setting in motion the wheel-lock, provided any sparks are generated; the probabilities that they would be seem to have been considered about equal to an even chance, with a small percentage in favor of failure, which accounts for the fact that a lighted match was held to be essential in wheel-lock gun shooting.

This gun has no tip stock, and the barrel is cut away on each side to allow the escape of the balls in case of premature explosions in the cylinder. There is a pistol of the same principle of construction at Woolwich. Both these arms show by their barrels that they were corned powder using weapons. A wheel-lock shoulder-piece eight chambered revolver of the 17th century in the Hotel Cluny at Paris

is in system similar to the one last described, but differs from it materially in the arrangement of the vents. There is a single priming channel from the pan to the rear of the cylinder, with eight corresponding tubes extending from the rear to within about a calibre of the front end, where a vent is pierced into each chamber. This arrangement was probably to prevent simultaneous explosion of the charges, and not an attempt to produce a better effect from the charge by igniting it directly in rear of the projectile. As in the 16th century gun, the priming channel and pan had to be refilled every time a chamber was discharged.

An elaborately finished Spanish gun, in the Cluny, probably of the early part of the last century, seems to come next in the chronological order of revolvers. This gun is a flint-lock; the cylinder is rotated by hand and is locked in the firing position, with a chamber in line with the barrel, by a pin which enters a hole in the rear end and which has to be withdrawn before bringing up a fresh chamber. The chief peculiarity of this gun is a magazine of priming powder immediately above a fixed pan, which serves for the four chambers of the breech; this magazine is hinged to the pan, and is fitted with a sliding bottom, which, when drawn out, is intended to allow a certain amount of the priming to fall into the pan, and when pushed back, to cut off the supply. The rear surface of this magazine serves also as a steel or striking surface for the flint, and is ribbed on its face. The gun has a tip stock covering the forward, and a cap enclosing the rear end of the cylinder; in using it it would seem that the priming powder in the magazine would inevitably explode; the priming fire would find its way to the other vents, and the lateral fire at the fore end of the cylinder would be directed into the other chambers and explode all the charges prematurely. In the armory of Warwick Castle there is a gun of about the same period that appears to be an attempt to insure greater safety in firing, at the expense of greater complexity of mechanism. It has a flint-lock and a hand-rotated four chambered cylinder. Each chamber is furnished with a priming pan and steel, which latter forms also the cover; therefore the firing of one charge is not so likely to ignite the powder in the other chambers. The tip stock is very light, so as not to cover the chambers; thus if a premature explosion took place, while there would be no material injury to the gun, the rest arm of the firer would probably be carried away. The cylinder seems to have been secured by a spring from the rear end of the barrel. An arm very similar in system to

the above is in the Tower armory, the breech system being composed of four distinct chamber tubes fastened together by two end plates and rotated by hand.

The next attempt at a magazine gun is shown in the Dafte gun, invented in England about the middle of the last century. There is evidently an endeavor, in this arm, to produce a more compact weapon, for instead of having a projecting pan and steel for each chamber, recesses are made in the periphery of the cylinder to form pans, and one steel was probably provided to stand over the breech and attached to the barrel. The cylinder containing six chambers is rotated by hand, and is locked when in firing position by a device like that in the pyrites wheel-lock gun. It would seem, from the holder of the steel being fastened over one of the chambers into which the fire would be deflected, that premature explosion would necessarily take place, that the steel would be broken off, and the gun rendered as useless as the man who fired it, at the first discharge.

In 1818, Elisha H. Collier, of Boston, Mass., patented a flint-lock shoulder-piece revolver. It had a priming magazine, a flue or channel that would conduct the fire to the different vents, a cap or shield in front of the cylinder which would direct lateral flame into the loaded chamber,—in short, all of the accessories that seem to have been so efficient in producing premature explosions. The cylinder was borne up against the barrel by a spring, and each chamber was counterbored at the forward end to receive the end of the barrel. This bearing up of the cylinder is maintained during the firing by a bolt which is thrust forward, when the trigger is pulled, by the action of a cam on the spindle of the hammer. Another flint-lock revolver was invented by a Mr. Wheeler, of Boston, in 1819. Its peculiar feature consists in a coiled spring made fast to the cylinder and to the arbor, which, being wound up, is intended to rotate the chambers automatically, an escapement device being operated by the action of the lock. In a marked degree it possesses all the properties that are so well calculated to discharge all the chambers at once.

In 1829, a New England boy, fifteen years of age, who had run away to sea from Amherst, Mass., where he had been at school, was shooting at porpoises off the Cape of Good Hope; being annoyed because he could have only a single shot before reloading his piece, he conceived the idea of a gun with several barrels, to be fired one after the other, and then concluded that revolving chambers with a single barrel would better answer his purpose. This conception he

proceeded to work out in wood, and the result so took his fancy that upon his return to the United States from Calcutta, whither his run away trip had landed him, he earned a little money at lecturing, and with it put his idea into metal. Half a dozen years later this invention was patented in England, and soon after in France and the United States: the problem of producing a practical magazine arm had been solved. In the first specification of the English patent granted to Samuel Colt, he claimed among other things, "the object of my principles, adaptations, and applications being to cause the said cylinder to revolve the distance from centre to centre of two contiguous chambers by the action of cocking the gun or pistol, and by the same action to lock the cylinder firmly in its place when so brought, and thus that no care or attention on the part of the person using the fire-arm is required in order to bring the charges into the proper place for being discharged through the barrel"; and that the arm was practical in "sixthly, in effectually separating the recesses (of the cylinder) in which the percussion tubes are placed from each other, so as to prevent fire communicating from the exploding cap to the adjoining ones."

The percussion cap had been invented, a Yankee boy applies it to the old revolving system, compels the action of the lock to rotate and lock the cylinder, and the problem that for four centuries had been vexing the gunmakers is solved—a practical magazine arm was produced. The Florida war, which followed so soon after the production of the Colt's revolver, gave the opportunity to prove its value in the field; an opportunity that was fully taken advantage of, in showing what such an arm could accomplish in the hands of men like Harney's rangers.

From that time the utility of the revolver became a fixed fact, and to-day, in 1880, it is the favorite side-arm ashore and afloat in all the countries of the world. As a shoulder piece it has never been extensively used; for, in the days of loose ammunition, the time taken to load the chambers militated against its efficiency for what was then considered long range fighting; and from its construction, the charges in the magazine—the cylinder—could not be readily held in reserve. Although numbers of Colt's revolving rifles were used in the Florida and Mexican wars, by plainsmen on the frontier, and even in the war of the Rebellion by Berdan's sharpshooters and by the infantry and cavalry under Fremont, in the shape of carbines and muskets, the place of the revolving principle as applied to military arms is and

was held to be upon the pistol; its duty to supply a rapid and successive fire at pistol practice range, a duty it has always performed satisfactorily, from the time that Fighting Jack Hayes of the Texas rangers attributed his successes to its aid, to the present time.

The history of the adaptation of the revolver to metallic ammunition is not a little curious, as an example of the way in which improvements in arms "grow" from what are apparently worthless devices. On the 3d of April, 1855, one of Colt's workmen, named White, patented a pistol, the principal feature of which was the boring of the chambers entirely through the cylinder in order to load from the rear; a leather gas check was used to stop the escape of the gas to the rear and laterally, a device entirely inefficient, as were most of those for accomplishing the same purpose when loose ammunition was used. This boring-through-the-cylinder arrangement was declined by Col. Colt, when offered to him, on the ground that it was worthless and had been patented in France twenty years before; and it was then acquired by Smith and Wesson, who, in 1858, when the Colt patents had run out, and when with improvements in metallic ammunition the breech-loading idea came to the fore, produced a breech-loading revolver, and for a time debarred other makers from boring through their cylinders to take the new cartridges; thus did the White device, originally considered worthless, become of great value to its possessors.

Within the two decades last past a great many changes and some improvements have been applied to the revolving type of magazine arms; but in general principle all the numerous revolvers of the present day are but so many modifications of the Colt's.

It would seem that the difficulty of disposing of the magazine in the repeating type of fire-arms, when that type is applied to pistols, has caused the retention of the revolver as a side-arm since the repeater has been so perfected for shoulder-piece work; for the breech of the pistol, from its size and shape, does not admit of the reception of a good magazine, while the placing of one longitudinally under the barrel is objectionable on account of the change of balance in the pistol hand as the charges are fired. Until a compact magazine, located at the breech of the barrel and having a quality of but slightly changing the position of its centre of gravity as the charges are exhausted, shall be produced,* we may expect to see the revolver retain-

* The production of such a pistol would furnish a side-arm as well balanced and convenient as the revolver, while it would eliminate one of the principal objections to the revolving type of arms, *i. e.* the firing across a joint; an objection that is noticeable in all the revolver pistols of the present day, and that becomes a serious defect when the

ing its position as the favorite side-arm. At the present stage of pistol-making it is difficult to comprehend how any repeater could excel the many excellences of the tried and trusted revolver.

Repeaters.

It is evident, from the definition at the beginning of this article, that a *repeater*, in the narrower sense, must be a breech-loader; and it is a well established fact that the breech-loading of small arms was not successful before the appearance of metallic ammunition. If these two statements be correct, we should not expect to find practical repeaters among the earlier fire-arms. Although there may be many such, I have been unable to hear of any records or specimens of match-lock or wheel-lock guns containing the germs of the repeating idea. This idea seems to have had four distinct steps of development: 1. Firing in succession charges superimposed upon each other; 2. Loading loose powder and ball charges into a breech-block and successively firing them from it, across a seam between it and the barrel; 3. Loading paper cartridges into the chamber and firing them in succession; 4. Using self-primed metallic ammunition and eliminating the operation of priming.

Porta, in his *Natural Magick*, 1658, speaks of a great brass gun or hand gun which may discharge ten or more bullets without intermission. The idea was to load with powder and ball alternately until the barrel was full. An intervening "dark powder" gave an interval between the firing of the separate charges so as to avoid the simultaneous explosion of them all. Whether this "dark powder," which may have been some kind of sand wadding, accomplished its purpose or not, Porta does not say, and there seems to be no good reason for supposing it did; but still it is supposed to have been a gun of this type to which Pepys alluded in his Diary, 1662, when he wrote, "After dinner, was brought to Sir W. Compton a gun to discharge seven times, the best of all devices that ever I saw, and very serviceable and not a bauble; for it is much approved of and many thereof made."

system is applied to shoulder pieces. Any one can, at the expense of a coat sleeve prove to his own satisfaction that the escape of gas from the joint between the barrel and cylinder of a very accurately made arm is quite appreciable, by firing his belt pistol from the position of "Left arm rest, aim!" allowing, while doing so, the barrel of the revolver to lie on the arm above the elbow and the face of the cylinder to drop inside and below.

There is the possession of the Winchester Repeating Arms Co. a flint-lock musket, invented by an American named North, in 1825, that was intended to fire several successive charges without using revolving chambers. This gun differs from an ordinary muzzle loading flint-lock musket, only in being provided with half a dozen vents with a lock-catch for each, and in having the lock, movable in a groove along the vented portion of the barrel, carry with it a magazine of priming powder. The gun was to be loaded with ordinary paper cartridges, one over the other till there was a powder charge abreast each vent; the distance between the vents being equal to the length of a cartridge. The lock was then to be pushed up to the forward vent and secured there by its catch in such a manner that the hole in the priming pan corresponded with it, and the first charge fired; the lock was then released, drawn back to the second vent, the priming magazine, by a cut-off arrangement, used to refill the pan, and the second charge fired, and so on till all the cartridges were used.

There is no evidence to show that the beautiful faith of the inventor was ever justified by the works of the gun; and assuredly in these degenerate days no one who knows anything of fire-arms would willingly fire the first charge from a fully loaded North gun—unless indeed by means of a very long string leading from the trigger through a very small hole in the wall of a good substantial bombproof. The fact that the specimen alluded to exists, with its barrel intact, strongly indicates that as a magazine gun it was never fired at all.

Another gun on the superimposed charge principle appeared in France in the first years of the use of the percussion lock. This gun, invented by M. Robert of Rheims, and afterward improved by MM. Gordon Aubry and Robert, had a series of locks and nipples enclosed in the stock under the barrel, each lock being shut off from the adjoining ones by a diaphragm, and all of them let off in turn by a pinion, which by an ingenious arrangement of a coiled spring and rack was for this purpose made to travel, by pressure on the trigger, along the inside of the stock. The distance between the nipples was equal to the length of a cartridge, as was the distance between the vents in the North gun. MM. Gordon Aubry and Robert were very particular in their direction for loading, and had marks on the rammer to show when the charges were properly home; like North they seemed to have had perfect faith that the charge next in rear of the one fired would prove an efficient gas check; though why they should it is

impossible to understand. Their claim for the gun is for "la facilité de faire partir plusieurs coups avec un seul canon et en superposant les charges."

But before the advent of metallic ammunition there were many attempts at producing magazine arms, attempts that would have been successful had the guns proved practical breech-loaders—the magazine part was not difficult—the fermature of the breech was the obstacle. It is possible that many arms of the type may have appeared earlier, but the first true repeater of which I have any knowledge is a flint-lock, loose-ammunition-using gun of the second decade of the present century, the invention of M. Henry, Ingénieur-Mécanicien à Paris. This gun had a powder magazine on the left side and a ball magazine on top of the barrel. By the action of the lever of the breech block a powder charge was taken from the side, a ball from the top, and at the same time the pan was primed. In speaking of the advantages of his gun M. Henry says:

"Ce fusil présente l'avantage d'être aussi vite chargé pour quatorze ou quinze coups qu'un fusil ordinaire pour un coup ; par conséquent, il est plus prompt à répéter son feu, d'autant qu'on n'a qu'à faire mouvoir un levier qui fait tourner dans un tonnerre en fer, deux noix en acier, dont l'une laisse le passage à la poudre sortant d'un tube elliptique qui se prolonge le long du canon pour arriver au tonnerre par la grosse noix qui, de son côté, prend la balle d'un tube contigu qui la contient et l'amène de force sur la poudre ; le levier étant ramené à son point de départ, procure ainsi la quantité de poudre nécessaire pour l' amorce du bassinet ; ensuite on n'a qu'à armer et à faire feu ; par conséquent, on peut tirer quatorze et quinze coups sans recharger. Ce fusil n'a point besoin de bagnette, ce qui gêne beaucoup dans l'exercise d'un combat ; il a la propriété de porter plus loin qu'un fusil ordinaire, la balle sortant forcée ; il possède, en outre, le précieux avantage de n'être pas sujet à crever, comme il arrive souvent, parce qu'il ne peut se charger par double ou triple charge," etc., etc.

This last "precious advantage" so plain to M. Henry early in the present century, was not very apparent to the ordnance authorities of the United States, till the twenty-five thousand muzzle-loaders recovered from the field of Gettysburg, nearly all with two, four, six and even twenty rounds in their barrels, demonstrated only too clearly that it was indeed an advantage too precious to be longer neglected.

From 1820 to 1860, the loose ammunition repeater appeared in various forms in this country and in Europe, always ingenious in

construction, usually too complex in its mechanism, and invariably failing for lack of a breech fermature, if for no other reason ; the idea of the arm was, however, so attractive that a system of its type was patented in the United States as late as 1860, after metallic ammunition had been in general use for some years. This system, patented by Paul Boynton, Jan. 3, 1860, was intended for a pistol, and consisted of separate longitudinal powder and ball magazines under the barrel, together with a circular one on the breech containing percussion primers. By revolving the barrel and magazines about a central arbor a motion was obtained which by an ingenious device was made to take a ball from the ball magazine, a powder charge from the powder magazine, bring them both into the breech-block in rear of the barrel and drop a primer into the vent cup; the hammer was fitted with a piercer, like that of the ordinary metallic ammunition revolver, instead of with the cupped recess that was used with percussion cap locks. Another system looking to the same result was patented by J. D. Moore in March of the same year.

Of repeaters adapted to the use of the paper cartridge and percussion cap there are numerous records, showing that the magazines were applied, longitudinally under the barrel to feed the charges backward, obliquely in the breech stock to feed forward, above, below, at the side and around the breech, in short in all the ways in which magazines are applied to modern repeaters. Noticeable among arms of this type are the ingenious guns of M. Cass, patented in this country in 1848, and of J. Swyney, also patented in the United States in 1855. The first of these guns had a magazine in the stock consisting of a series of cartridge cells fastened upon an endless belt, which was perforated under the seat of each cell to allow the passage of a rammer that pushed the cartridge from its cell into the chamber, when this last was by the movement of the belt brought into the proper position; the action of a jointed lever under the breech moved the belt the required distance to bring the cartridges into the loading position, and then operated the rammer that successively loaded them into the chamber; a revolving disk, carrying as many nipples as there were charges in the magazine, and operated by the hammer in cocking, brought up a fresh percussion cap for each fire. The Swyney gun had a longitudinal charge magazine under the barrel, along which the charges were moved by a spiral spring as in the modern guns having magazines of that type, and a cap magazine in the stock. The action of a guard lever moved the breech block down to receive a

cartridge from the magazine, carried it up to the firing position, and at the same time capped the nipple on the block. Thus it appears that the magazine part of the repeater was an accomplished fact, while satisfactory breech loading was still an unsolved problem; unsolved, although by many excellent breech-loading devices, and notably by the old Sharp's system, it was very near solution.

Before attempting to trace the progress of the repeater through its post-percussion-cap course, it is first necessary to glance, in a cursory way, at the antecedents of that common parent of modern breech-loading magazine and machine arms, the self-primed metallic shell cartridge.

In 1812, Pauly, a French artillery officer, patronized and encouraged by Napoleon I, always anxious for the advent of the breech-loader, patented a breech-loading arm "et des cartouches de composition particulière." In a report made to the Société d'Encouragement pour l'Industrie Nationale, in July, 1814, Brillat de Savarin says of Pauly's cartridge, "La charge est renfermée dans une cartouche montée sur un culot de cuivre percé dans son centre et creusé de manière à recevoir une amorce de composition muriatique, sur laquelle vient frapper un barreau de fer mu par le grand ressort; la poudre frapper détonne, l'entincelle qui en résulte enflamme la poudre et le coup part avec un extrême rapidité." Paulin Desormeaux in speaking of these cartridges says: "Ces cartouches nouvelles portent avec elles une rosette d'amorce *ou double culasse mobile* qui sert de dépôt au résidu de la poudre, et, cette rosette étant renouvelée à chaque chargement, les armes sont aussi propres après un long service qu' auparavant." A cut of the gun with the charge in place shows that the cartridge was a paper envelope one, the rear of which was enclosed in centre primed copper shell; the gun was of the concealed lock firing-pin type. The advantage of centre priming was appreciated, and the fact that the shell was spoken of as "a movable double breech," would seem to show that its effect as a gas check was known; but be this as it may, a couple of years after de Savarin's report the gun was improved backward to use a detached primer, and eventually to the use of a flint lock, although the breech mechanism so far in advance of its contemporaries was retained for many years.

In 1836, Mons. Robert, of Paris, produced a copper shell cartridge made in two parts, a cylinder, and a cup that formed the flanged head which was filled with fulminate; and shortly after the Flobert cartridge appeared; this last had a drawn copper case and a thick head

which was filled with fulminate also. It would seem that both these cartridges provided good gas checks, but they were used only for fulminate cartridges in small calibre weapons, and the principle was not applied to long range or military guns.

In 1846, M. Houiller, of Paris, invented rim, centre, and pin fire cartridges with metallic shells. In the same year, Lefancheux, another Parisian gunmaker, improving upon a multi-barrel cap-lock pistol of the "pepper box" type, bored his cylinders entirely through, loaded them at the breech, and used pin-fire cartridges with copper gas checks, card-board bodies and metallic anvil primers. Lefancheux made a long step in advance; indeed he had all the requisites for a metallic cartridge with the exception of the flanged head. In 1854, Smith and Wesson produced a flanged head metallic cartridge which was also centre fire, but deficient in having no anvil, the fulminate being placed between the head of the shell and an indurated or hard metal disk forced in as far as the flange, and forming both a diaphragm to separate the fulminate and powder, and a resistance to the blow of the hammer. In 1856 the same manufacturers patented a loaded bullet, the powder being contained in a hollowed out recess, and held in place by a steel disk which was the bottom of a copper or brass case pressed into the cavity in the bullet; this case contained the fulminate upon the steel disk, which in turn was covered by a disk of cork. A firing-pin entering through a hole in the top of the brass case was pressed through the cork and brought in contact with the fulminate. A blow on the firing-pin by the hammer was then expected to detonate the fulminate and so explode the powder. Sometimes it did.

In 1856 the Maynard cartridge appeared. This was a metallic shell, centre fire, unprimed cartridge carrying a double canalured ogival pointed bullet, with the lubricant in the canalures after the manner of most of the service cartridges of the present day. It was for use in the Maynard breech-loader and had some very good points. In 1860 many of these cartridges were made at the Frankford arsenal, where a head in the shape of an attached disk was soldered on. In 1858, G. W. Morse patented a metallic shell centre primed cartridge with an anvil in the shape of a forked wire with the legs soldered to the sides of the shell, the intersection of the two legs being the point to receive the blow. This cartridge had a rubber packing in the head which surrounded and supported the capsule containing the fulminate, the latter fitted over the anvil. But the advantage of the centre

primed cartridge was not fully understood till some years later, the rim-fire Spencer being used in the repeater of that name during the war of the Rebellion, and in the Henry repeater also. The rim-fire cartridge proved itself to have the property of providing a good gas check, and the capability of being moved in the magazine and loaded into the chamber without requiring the use of complicated mechanism; but it was defective in that it required a comparatively large fulminate charge to fill the rim-space, and that the fulminate was not always evenly distributed, defects that in the one case caused a great strain on the head, often enough to burst it, and in the other frequent miss-fires.

When the war of the Rebellion proved that the breech-loader was the arm of the immediate future, it gave an impulse to the improvement in metallic cartridges that resulted in the great activity that was displayed in that direction, especially in the United States from 1864 to 1872. The best talent of the Army Ordnance Corps gave the subject its attention. Cols. Treadwell, Laidley, Benét, Benton, and Crispin, and Capt. Prince, experimented and made researches in this direction, with results that speak for themselves in the many excellences of the cartridges now manufactured at the Frankford arsenal. In this period appeared the Martin folded, the Millbank close folded, so-called solid, and the Hotchkiss really solid headed shells, and the Berdan, Farrington, and many other excellent primers; immense works for the manufacture of small arm ammunition were established, a great industry was created, and the American centre primed metallic cartridge came into existence to challenge the admiration of the world. All nations that pretend to maintain a fighting force use to-day the American small arm ammunition, either manufacturing it themselves or obtaining it from this country; but there is very great difference of opinion as to the comparative excellence of certain points. It is generally conceded that the cartridge case shall be of the drawn metal centre primed type*—even conservative Eng-

* The cartridge shell best adapted to navy use seems to be one of the solid-head outside primed type, of copper, of "the copper lined," like that manufactured by the Coe Manufacturing Company, or of brass, nickel plated or otherwise protected from corrosion; solid head because the extraction is freer than with the folded one, an important consideration when the ammunition is to be used in magazine and machine guns; outside primed, because it can be reloaded aboard ship and thus materially reduce the expense of target practice; and of the metal or metals as mentioned, because experience has shown that the brass shell

land being on the point of giving up her wrapped metal Boxer shell, a shell experimented with and patented by Gen. Rodman and Col. Crispin, in 1863, and by them rejected as inferior to drawn metal; but the questions of copper or brass, folded or solid heads, canalured bullets with lubricant in canalures or smooth bullets with paper patch and wad lubricant, kind of primer, kind of lubricant, shape of body, cylindrical or reduced (bottled), shape of bullet and proportion of powder charge to weight and shape of bullet, have never been settled, although there has been much investigation in this direction, while the wide field of determining the character of the powders to be used with bullets of different weights and calibres is neglected and unworked.

To return to the repeater; as has been shown, the practical modern repeater only awaited the advent of metallic ammunition, and as may be supposed appeared with it. In March, 1860, the Spencer repeater was patented, and the Henry in October of the same year. The first of these guns, with a magazine in the stock and a breech-block swinging downward and backward by the action of a guard lever, was the favorite cavalry arm of the war of the Rebellion, many thousands of them seeing service in the hands of the mounted troops of the United States and in the navy; while the second, with a magazine under the barrel and a guard lever operated, backward sliding, breech-block, was also extensively used by the cavalry in the same war. Both these guns were excellent arms, and even in the light of recent developments one can only say that as military repeaters they were perhaps defective in using lever-worked breech-blocks instead of sliding bolts; in the position of the loading orifices of the magazine—that in the one being in the butt plate, and in the other near the muzzle; in using rim-fire ammunition, and, in the Henry, in leaving the magazine exposed to the entrance of rain, dust, sand, and mud. After the war of the Rebellion, so great was the activity displayed in working out the repeater idea that, in the United States alone, the number of patents issued for devices of this kind, in the period extending from 1873 back to 1836, reached 120, most of which were brought out later than 1865. Since 1873, many more have been added to the list, the greater number crude and worthless as patented, "mere baubles," in the language of the cynical Pepys, but nearly all containing ideas that,

is not to be relied on after being stored in a ship's percussion locker for a couple of years. The copper-shell, folded head cartridge of the Frankford arsenal is a most excellent one, but it cannot be reloaded and its extraction is difficult. Neither of these objections apply to the Frankford reloading cartridge.

in combination with those of other guns of the type, result in practical arms. The "growth" of the well-known Winchester repeater is illustrative of this combination of principles. The origin of the Winchester was the Jennings, a bolt gun, with an under barrel magazine, patented in 1849. The next year the patent was bought by Smith and Wesson, who manufactured the guns and adapted them to use the wooden shell unprimed cartridges invented by Walter Hunt in 1848. Smith and Wesson spent five years in improving the gun, applied to it several patented devices, and then, in 1855, sold it with its patents to the Volcanic Repeating Arms Company, which was organized to manufacture guns and pistols on the Jennings plan, adapted to use the loaded bullets patented by Smith and Wesson in 1856. The Volcanic Repeating Arms Company tried for two years to bring the gun up to a practical standard, made some improvements, and then went into insolvency. The gun with its improvements was then bought by the New Haven Arms Company, organized to manufacture it, who in turn spent two years and much money in improving it, and eventually, in 1860, produced through the superintendent of the company's works, Mr. B. F. Henry, the Henry repeater.

The Jennings gun had been improved past recognition. The Henry was improved, in 1866, by Mr. Nelson King, who replaced the magazine in one with the barrel, opened slotted its whole length. It was arranged to load by dropping the cartridges in near the muzzle after pushing the feed spring up into a cap which swung clear of, and opened the magazine, by a tubular one that received its charges against the spring through an orifice in the breech. This gun of many ideas was named the Winchester, after the president of the company, which was reorganized under the name of the Winchester Repeating Arms Company, and which has since manufactured the arm, acquiring the patents of Fogerty and Spencer, in order to suppress the making of guns of those names. In 1873 the gun was remodeled to take centre primed ammunition, and then became the Winchester repeater as we know it to-day.

During the last decade, the military authorities of the world have been seriously considering the adoption of the magazine gun as a standard arm for mounted troops and men serving afloat. As regards this country, the army has been asking for a magazine arm with which to meet the Indians often armed with that favorite weapon of the frontier, the Winchester, and the request has been met by the War Department by ordering, in 1877, a board of ordnance officers to select and recommend a magazine gun for the military service. This

board in the following year tested* and experimented with some twenty systems brought before it, and reported as follows:

"The board, in the discharge of these duties, has tested all the guns presented uniformly and in the manner that seemed to it best

* The board, after discussion, adopted the following rules and tests for the trial of all magazine guns submitted under the order:

The piece to be first fired ten rounds by the exhibitor, as a test of safety; the same firing to be also a test of rapidity by one familiar with the arm. The time to be noted in the record.

The firing to be then continued according to the rules annexed, by an employé of the armory, or soldier detailed by the War Department.

The service-cartridge to be used in all cases.

No persons will be admitted to the firing-ground but the agents or exhibitors of the gun immediately under trial, and such other persons as may be specially invited by the board.

The handling of guns by their representatives at *any* time after the preliminary tests for safety is *forbidden.*

Any arm which has been submitted to the board and entered upon the record, shall remain in the hands of the board for such time as may be necessary to make drawings explanatory of its mechanism.

If a gun become disabled or unserviceable, all further tests will be discontinued, and the proprietor informed of the fact. If the gun be altered and resubmitted to the board, it will be treated as a new gun.

REGULAR TESTS.

Safety tests: To be fired ten rounds by the exhibitor or with a lanyard.

I.—Rapidity with Accuracy.

The number of shots which, fired in two minutes from the gun—both as a magazine-gun and as a single shooter—strike a target 6 feet by 2 feet at a distance of 100 feet. Any cartridges missing fire in this or other tests to be tried with a prick punch, or opened to ascertain the cause of failure. The test to be begun with the chamber or magazine filled; other cartridges to be disposed at will on a table.

II.—Rapidity at Will.

The number of shots which can be fired in one minute, irrespective of aim, under the same circumstances as in Test I.

III.—Endurance.

Each gun to be fired 500 continuous rounds without cleaning, using the magazine. The state of the breech mechanism to be examined at the end of every 50 rounds.

adapted to determine the question of their suitability for the military service, as well as to determine their comparative merits in that respect.

IV.—Defective Cartridges.

Each gun to be fired once with each of the following defective cartridges: 1. Cross-filed on head to nearly the thickness of the metal. 2. Cut at intervals around the rim. 3. With a longitudinal cut the whole length of the cartridge, from the rim up. A fresh piece of white paper, marked with the number of the gun, being laid over the breech to observe the escape of gas, if any occur.

V.—Dust.

The piece to be exposed in the box prepared for that purpose to a blast of fine sand-dust for 2 minutes; to be removed, fired 20 rounds, replaced for 2 minutes, removed and fired 20 rounds more.

VI.—Rust.

The breech mechanism and receiver to be cleansed of grease, and the chamber of the barrel greased and plugged, the butt of the gun to be inserted to the height of the chamber in a solution of sal-ammoniac for 10 minutes, exposed for two days to the open air standing in a rack, and then fired 20 rounds.

VII.—Excessive Charges.

To be fired once with 85 grains of powder and one ball of 405 grains of lead; once with 90 grains and one ball, and once with 90 grains and two balls. The piece to be closely examined after each discharge.

Supplementary Tests.*

1st. To be fired with two defective cartridges, Nos. 1 and 2, and then to be dusted five minutes, the mechanism being in the mouth of the blow-pipe, and closed, the hammer being at half-cock; then to be fired 6 shots, the last two defective Nos. 1 and 2; then without cleaning to be dusted with the breech open, and fired 4 shots. The piece to be freed from dust only by pounding or wiping with the bare hand.

2d. To be rusted for 4 days after immersion as before, then fired 5 rounds with the service cartridge; then without cleaning to be fired 5 rounds with 120 grains powder and a ball weighing 1200 grs.; the gun to stand twenty-four hours after firing without cleaning, and then to be thoroughly examined.

3d. Facility of manipulation by members of the board.

4th. Liability to accidental explosions of cartridges in the magazine.

Additional tests may be made by the board to clear up doubts raised by previous trials.

*To be applied only to such arms as have passed through the regular test in a manner satisfactory to the board.

"The regulations for the trials adopted by the board are given in the appendix.

"Its experiments to test the liability of accidental explosion of cartridges in the magazine seem to show that there is little probability of such explosion when using the inside-primed service-cartridges, or even with the exterior-primed cartridges direct from the factory, when fabricated and inspected with the care and attention usually given them. With cartridges reprimed in the field or garrison, risks may be introduced which have not come within the scope of the investigations of the board.

"From the satisfactory manner in which the Hotchkiss gun, No. 19, has passed these tests, and from its combination of strength, simplicity, and great effectiveness as a single loader, the board is of the opinion that the Hotchkiss gun No. 19 is suitable for the military service, and it does, therefore, recommend it as such."

Signed: J. G. BENTON,
Lieutenant-Colonel of Ordnance, President of Board.
F. H. PARKER,
Major of Ordnance.
J. P. FARLEY,
Major of Ordnance.

In 1879, a thousand Hotchkiss guns were issued to the army for trial in the field, and in the same year the Naval Bureau of Ordnance adopted the same gun for the standard shoulder-piece, and at the same time took a few Remington-Keene and ordered a few Lee guns for trial. In 1880, the current year, the Interior Department ordered a thousand Remington-Keene guns for use in the hands of the Indian police. General Miles has requested that the troops under his command be armed with the Lee gun, as he considers it the best known arm for Indian fighting.

England has been awaiting the advent of a magazine arm adapted to the awkward Boxer cartridge, and will wait long if the reason for delay continues to hold good.

France has adopted the Kropatschek for its navy, and intended to take fifty thousand of these guns for use afloat, but has lately concluded to use them only experimentally and has but two thousand in service.

Russia had a few Evans' guns a half dozen years since, and is now experimenting upon magazine guns.

Germany is doing nothing in this direction.

Austria has adopted the Fruwirth gun for its navy, and has forty thousand of them in the hands of its shore troops who guard the frontier, doing customs work, etc. The government is also experimenting with the Vetterli.

Italy has adopted the Winchester for its navy, and has made a few thousands of the guns at Venice. For shore service the government is endeavoring to convert the single loading Vetterli into a magazine gun on the plan of Capt. Bartolemeo.

Turkey has the Winchester for it cavalry.

Switzerland has adopted the Vetterli magazine gun, and is the only country which has thus far put a repeater into the hands of the infantry of the line.

Norway has introduced the Krag-Petersen into its navy. The writer has been unable to learn that any other countries are doing anything in the way of adopting magazine arms. All the military repeaters now in use, except the Winchester, are of the sliding bolt type of breech-block, and all of them, except the Hotchkiss and the Lee, have magazines under the barrel.

The weight of the military opinion of the world seems to decide, at present, that the repeater shall be used as a single loader for ordinary fighting, with the charged magazine held in reserve for critical moments; that it shall be so devised as to be capable of being so used; and that as a single loader it can be as easily manipulated and as rapidly fired as any gun on a single breech-loading system; that the breech-block shall be of the bolt type, that the piece shall be so constructed that the magazine and all working parts connected with it may be disabled without detracting from the usefulness of the arm as a single loader; that, other things being equal, same number of charges in magazine, etc., the centre of gravity of the charged magazine shall fall between the rest hand and the shoulder of the man firing the gun; that the magazine shall be capable of taking and the gun capable of firing cartridges of different lengths; and that it shall be readily and rapidly charged.

The fact that so many military repeaters have tip stock magazines, bad as regards position, is due to the desire for greater stowage capacity than one in the butt stock will furnish without making the piece very clumsy.

Classification of Magazine Arms by Board of United States Army Ordnance Officers, 1878.

Classification of magazine-arms, founded on the method by which cartridges are fed from the magazine.

Magazine-arms — supply chamber with cartridges from—

- 1st, butt-stock
  - 1st, by a spring
    - 1st, direct …… Hotchkiss. Lewis-Rice. Spencer.
    - 2d, indirect….
      - 1st, by rotating barrel about axis parallel to it into line with magazine. …… Scott and Triplet
      - 2d, to position opposite receiver …… Clemmons.
  - 2d, by a ratchet, which is—
    - 1st, automatic …… Chaffee.
    - 2d, operated by hand. …… Springfield-Miller.
  - 3d, by a spiral cam (screw-motion). …… Evans.
- 2d, tip-stock .. by a spring— on a carrier which is—
  - 1st, sliding, at right angles to axis of b re …… Winchester. Henry. Hunt. Vetterly.
  - 2d, rotating—
    - 1st, to position oblique to axis of bore… Burton. Ward-Burton. Sharps. Remington.
    - 2d, to position parallel with axis …… Tiesing. Burgess.
  - 3d, sliding and rotating— …… Buffington.
- 3d, magazine on top of barrel — by a spring— to position parallel to axis of bore and above receiver— and by gravity into line with axis of bore. …… Franklin.
- 4th, magazine below bolt — by a spring (vertically)— to position opposite center of chamber. …… Lee.
- h, revolving chambers. …… Hodges. Colt's repeat'g-rifle. Revolving pistols.

Classification of all magazine-guns before the Board, founded on the motions of the principal part by which the breech is opened and closed.

Breech-loading small-arms have—
- fixed chambers closed by—
  - movable breech-blocks which are—
    - 1st, sliding in line of axis of barrel by—
      - 1st, direct action, *i. e.*, bolt-guns having—
        - 1st, concealed locks: Hotchkiss. Remington. Burton. Ward-Burton. Franklin. Lee. Sharps Rifle Company.
        - 2d, center locks: Hunt.
      - 2d, indirect action *i. e.*, moved by levers from—
        - below: Winchester. Burgess. Tiesing.
    - 2d, sliding and rotating: Buffington. Chaffee.
    - 3d, rotating about an axis— at 90° to axis of barrel, and— horizontal, lying—
      - 1st, above axis of barrel, and in—
        - front: Springfield-Miller. Springfield-Clemmons.
      - 2d, below axis of barrel, and in—
        - front, moved from— below (by a lever): Lewis-Rice.

In preparing this article I have consulted and extracted from the United States Army and Navy Ordnance Reports, the United States French and English Patent Reports, and the writings of Col. Colt, Col. Church, MM. Paulin Desormeaux, and others. I am indebted for aid and information to Gen. W. B. Franklin, Mr. C. M. Spencer, and Mr. T. G. Bennett, Secretary of the Winchester Repeating Arms Co. I do not feel at all sure that the specimens I have selected as illustrative of the different steps are the earliest or latest of their type, or that they best fulfil the duties assigned them; my endeavor has been, by the use of references at hand, simply to indicate in a very general way the development of the magazine gun idea from its inception to the present day.

HARTFORD, CONN.; June, 1880.

Since the foregoing paper was prepared there has been a marked forward movement toward the general adoption of magazine rifles.

Germany has experimented with several, and at one time seemed to favor the Loew system, similar to, if not identical with one brought out by Lee some years ago; it consists of a detachable magazine that grasps the piece forward of the trigger guard; its advantage is that it can be readily applied to any single loading bolt-gun; its disadvantages are that when upon the piece it is very awkward, and when detached very clumsy for transportation upon the person. England is asking for a good butt-stock magazine, lever-action carbine, and has shown a little inclination toward the Martin-Spencer, a gun like the old Spencer in general principles, but charging the magazine through the receiver instead of through the butt-plate. Nearly all European countries are searching for economical systems upon which to convert the single loaders at hand into magazine arms. China is at present taking five thousand Hotchkiss rifles, and the Argentine Republic is endeavoring to decide upon the magazine arm to be procured in this country for the arming of her cavalry.

The United States Navy has just taken a thousand new model Hotchkiss rifles, of which the new modeling consists in replacing the side cut-off and bolt-lock by two parts, one on either side of the receiver, and in fitting the receiver into the stock differently; these changes make the gun stronger in those places where in service it had been found weak.

The army has purchased no magazine arms since it took a thousand Hotchkiss carbines about two years ago; these arms have gener-

ally given satisfaction to the people into whose hands they were put when magazine arms were desired. The stocks have broken badly, owing to an inherent weakness in that point—a defect that has now been eliminated. By authority of congress an army board made up of officers of all arms of the service is to meet in New York next July to investigate magazine gun systems, and recommend the one or two best adapted for use in the army.

In my opinion the Hotchkiss possesses more of the desiderata of a magazine arm for the navy than any other at present procurable.

The Lee system is very attractive in that it allows the shipping of a charged magazine in the same time that it would take to put a single charge into any kind of a tube magazine or into the receiver of a single loader; and in that it allows the transportation of ammunition upon the person, in the magazine, as conveniently as in any other way, and consequently allows the use of several magazines for each piece. Further, the detaching of the magazine removes all chance of the disabling of the piece as a single loader, through accident to the repeating parts, and renders unnecessary some of the more complicated and delicate parts of the ordinary magazine systems, viz. cut-off and cartridge stops; on the other hand, this detaching renders the magazine liable to be lost, but this liability is so small that the advantages of the detaching plan would seem to greatly outweigh it.

Unfortunately, owing to business complications among the owners of the gun, no one has yet been able to obtain any considerable number of Lee arms, and the three hundred ordered for trial in the navy have not yet been made, although the order was given nearly two years ago.

NATIONAL ARMORY, SPRINGFIELD, MASS., March, 1881.

NAVAL INSTITUTE, ANNAPOLIS, MD.

NOVEMBER 4, 1881.

REAR ADMIRAL C. R. P. RODGERS, U. S. N., in the Chair.

AIDS TO NAVIGATION.

BY LIEUT. COMMANDER F. E. CHADWICK, U. S. N.

It is difficult to realize that in 1816, one of the most important lights on the coast of Great Britain, that of the Isle of May, was but an open coal fire on the top of a tower; that until 1809 the famous Eddystone was lighted by twenty-four tallow candles, burned in a lantern without reflectors or any other means of increasing their intensity, and that preceding 1780 there was nowhere any brighter means of lighting than these.

At this last date came together the inventions of the parabolic reflector as applied to such purposes, and the argand burner: these were the beginning of a revolution in the systems of coast lighting, though their application was slow, due partly to the fact that there was under the best of circumstances nothing like the present interchange of scientific thought or discussion, and partly to the almost incessant wars and social upheavals of the period, which generated intense national antipathies and paralyzed international intercourse.

The honor of these advances in lighthouse illumination is due to France, as is that of most of the succeeding ones of prime importance. The work of Argand and Teullère was perfected by Augustin Fresnel (the elder of two brothers, both of whom achieved eminence in lighthouse engineering), when in 1822 he first used what is known as the Fresnel lens. Perhaps it may be wrong to say that Fresnel was the inventor, as Buffon, the great naturalist, had proposed to grind out of a solid piece of glass a lens in steps or concentric zones, and

Condorcet in 1773 suggested the building of such a lens in separate pieces: Sir David Brewster also published in 1811 an account of such a mode of construction; but Fresnel's invention was made independently and in ignorance of all these, and went beyond them also in determining the radius and centre of the curvature of the generating arc of each zone, instead of having the surfaces zones of concentric spheres. He was thus original in the methods actually employed, and fairly has the reputation due the first practical designer and user.

In 1783 the improved system of reflectors and burners was applied to the tower of Cordouan at the mouth of the Gironde river, France, though some experiments had been made at smaller lights a little earlier. The year preceding, this lighthouse, the finest architecturally considered in the world, had been fitted with eighty flat wick lamps, with segments of spheres as reflectors, "but the light was so poor that mariners earnestly requested a return to the preceding system of a coal fire, the latter having been substituted for a wood fire some years before."*

Scientific lighthouse illumination is thus the growth of the last hundred years. The changes may be divided into three periods: that of the Argand burner with parabolic reflector (1780); the Fresnel lens and multiple burner (1822); and the application of gas and electricity in our own day. Changes too have taken place in oils as well as in lenses and burners, the sperm oil of the early part of the century giving way in this century to lard oil, and now this and the colza and olive oil of Europe are alike yielding in a great degree to mineral oil, which is much more convenient in use, much less expensive, and gives better general results.

The growth and management of our own lighthouse system is of course the most interesting to us. It is instructive as showing how from want of system and foresight a small government organization in a country like our own, whose extent, population and necessities have so wonderfully expanded, may become a monument of inefficiency, and indeed must, where the question to be dealt with is a scientific one and it is left to the haphazard control of the officeholder. It required the efforts of nearly twenty years on the part of a few public spirited men, in the face of bitter struggle and opposition, to lift the establishment to a plane where it had opportunity for its proper development. The change finally came in 1852, and to no one is the

* Illumination and beaconage of the coasts of France.

honor of this great and radical reform due so much as to Rear Admiral Thornton A. Jenkins, whose earnestness and ability in this matter deserve every recognition.

The earliest authentic date that can be used in connection with our lighthouse system is that given by Mr. A. B. Johnson, chief clerk of the lighthouse board, in his excellent paper on our Lighthouse Establishment in Appleton's Annual Cyclopedia for 1880. This is found in a petition dated March 9, 1673, from the citizens of Nantasket, Massachusetts (now Hull), for the lessening of their taxes, because of the material and labor they had expended over and above their proportion in building a beacon on point Allerton, near the entrance to Boston harbor. It appears this beacon was lighted, at least at times, by fire-balls of pitch and oakum, which were burned in an iron grate on top.

"The first lighthouse properly so-called on this continent was built at the entrance to Boston harbor, on Little Brewster island, in 1715–16, at a cost of £2285 17s. 8½d. It was erected by order and at the expense of the general court of Massachusetts bay, and it was supported by light dues of 1d. per ton on all incoming and outgoing vessels except coasters, levied by the collector of imports at Boston."* Seven others were built before the Revolution, presumably by the colonies in which they were situated and when circumstances were such that attention could once more be given to peaceful things. Congress, to whom by the constitution of the new republic the power to regulate commerce was granted, passed an act in August, 1789, whereby the general government took upon itself the support of all lighthouses, beacons and buoys to be established, and of all lighthouses which had been previously maintained by the several states, and which should be ceded by these states to the United States. Acts of cession were passed by the several states, and the federal authority became responsible for the entire support of aids to navigation within our borders. There were at this time the following lights in existence, and I give the dates of their establishment as far as I can determine them: Portsmouth, New Hampshire, date unknown; Little Brewster island, near Boston, 1715; Gurnet, near Plymouth, 1769; Brant point, Nantucket, 1746; Beaver Tail, near Newport, Rhode Island, 1761; Sandy Hook, 1764; Cape Henlopen, date unknown; Charleston, South Carolina, 1767.

*Appleton's Annual Cyclopedia. A. B. Johnson.

The act regarding the transfer of the lighthouses likewise designated the secretary of the treasury as the controlling officer. In 1792 the office of commissioner of the revenue was established, and under the secretary of the treasury he was made general superintendent of lights; the collectors of customs acted as local superintendents in their own customs districts, and were supposed to look after the supply of oil, to exercise a certain authority over contractors, and to make a yearly inspection of the lights. The office of commissioner of the revenue was abolished in 1802, and the secretary of the treasury, then Mr. Gallatin, resumed the general superintendence of the lighthouse establishment, and it was so held until 1813, when the office of commissioner of the revenue was re-established. In 1817 there was a second abolition, the act to take effect in 1820, and in this latter year the superintendency fell to the fifth auditor, Mr. Stephen Pleasanton, who held the position for the long period of thirty-two years, or until the present establishment was organized.

In March, 1812, an act had been passed authorizing the secretary of the treasury to contract with a Mr. Winslow Lewis for the fitting and keeping in repair all the illuminating apparatus of the lighthouses the United States, at the same time purchasing his patent right to the "new and improved manner of lighting lighthouses by reflecting and magnifying lanterns." The first contract was for seven years, but it was afterwards extended, and for more than thirty years Mr. Lewis was the foremost figure of the establishment; building and repairing the lighthouses or altering the character of the lights much at his own discretion. The patent referred to was one which ought never have been granted, as there was not any pretence that the reflectors were other than the parabolic reflectors in use for years in Europe, and the magnifying lenses were simply heavy glass bull's-eyes, in some cases four inches thick, which, instead of increasing the intensity of the light, diminished it enormously. Nothing can show more decidedly the low state of scientific knowledge in this country at that time, and especially the want of it on the part of the superintending authority of the lighthouse establishment, than the fact that such a patent could be granted and an application of it made in our lighthouses.

The following letter from Mr. Pleasanton to Mr. Lewis gives an example of the loose management which existed under the former's administration, and shows how fully the establishment was in the

hands of an individual upon whom there was practically no governmental check whatever:

FIFTH AUDITOR'S OFFICE, Dec. 15, 1835.

Sir:—I perceive by a Mobile paper which I received this morning, that the Mobile light has been refitted by you as a revolving light. As the Pensacola light is a revolving light, and not many miles distant from that at Mobile point, the changing of the latter from a stationary to a revolving light is complained of as an injury to navigation.

In my arrangement with you for fitting up the Mobile point light last summer, it was not expected, nor contemplated, that you would refit as a revolving light, and I am very sorry you have done so.

Will you be good enough to state to me the reasons for changing this light from a stationary to a revolving light?

I am, &c., S. PLEASANTON,

Fifth Auditor and Acting Commissioner of the Revenue.

WINSLOW LEWIS, Esq.

Mr. Lewis answers at length, simply endeavoring to show that what he had done was the proper thing to do in his own judgment and in that of many others. There is no sign that he considered there was any higher authority than himself.

Lighthouses had increased rapidly: in 1820 there were fifty-five; in 1837 there were two hundred and eight, and twenty-six floating lights. Congress had evidently granted almost every application. There was no scientific selection of sites, the lights being established chiefly at the petition of individuals. The building was given out by contract, Mr. Lewis being the largest contractor and builder; his lamps and reflectors were still in use, and in the whole twenty-five years of his connection with the building, repairing and fitting of lighthouses there had been not one step in advance, except that the greater number of his "magnifying lenses" had been removed and the lights allowed to show naturally. Lighthouses were established or changed without any notice to mariners; the lighting of so important a light, for instance, as Barnegat being advertised simply in the paper published at the little village of Egg Harbor; and the fifth auditor, upon complaint being made by ship owners of this want of notice, states in his official answer, that "it would occur to any other persons than those making the complaints that it would be more proper as interested parties for them to give the necessary notice to vessels in which they are concerned."

Mr. Pleasanton's own ideas of what lighthouses should be are given in a rebuttal of some complaints made about this period; they are

curiously crude, to apply to them the mildest designation possible. He says: "The lighthouses I have caused to be built have been planned by men perfectly acquainted with the subject, and consist generally of four classes, viz. the largest class are sixty-five feet high, diameter twenty-five feet at base, graduated to twelve feet at top; deck fourteen feet; lantern sufficient to contain twenty-one lights, fourteen by twelve inches. The second class are fifty feet high, twenty-two feet diameter at the base, eleven feet at the top, deck thirteen and a half feet, walls four feet thick at base, two feet at top; lantern sufficient to contain twenty-one lights, thirteen by twelve inches, in each octagon," and so on, the third class forty feet high, the fourth thirty. He also says: "Experience has shown that a lighthouse higher than sixty-five feet in all our southern country where the coast is low, would be entirely useless, as during the summer months particularly a haze or mist is found to arise from the ground and float in the air at the distance of eighty or ninety feet, and by having a lighthouse sixty-five feet with a lantern ten feet, the light appears below the mist and is seen with its natural brilliancy a great distance at sea; whereas if the tower was carried one hundred feet or more the light would be entirely obscure." This sage observation must have been overlooked by our lighthouse board, as our southern coast is now dotted with lofty towers of more than one hundred and fifty feet, and no complaints have been heard on this score.

Of course so loose a state of affairs as these statements show could not remain without notice, and Nov. 30, 1837, we find a communication from Messrs. E. & G. W. Blunt, of New York, to the secretary of the treasury, giving in greater detail than can be found in any other paper of the date, the shortcomings of the system. The lamps were complained of as poor, the reflectors as of various and irregular shapes, and as not properly adjustable. At Watch Hill it is stated that before each light (several lamps and reflectors being set in a frame together in the old catoptric system) there is placed a thick piece of glass, the same as that used for a ship's deck-light, thus showing that even at this date this colossal piece of ignorance, which I have already spoken of, still existed pretty generally; the last in fact did not disappear until 1840. The Blunts' letter also stated that the Watch Hill light, which was revolving with two frames of lamps, had *no* reflectors in one frame and there were several wanting in the other. It also complained of the want of notice to mariners, of the want of proper inspection, of the want of a system of testing oil, and

of the want of a list of lights. Altogether the paper, which no doubt was a truthful representation of affairs, was a very bad showing for the establishment and the country: it ended in asking that the commission of naval officers ordered to investigate the subject of our lighthouse system be extended to the location, construction and management of our lights. The commission referred to was that ordered by the act of March 3, 1837, by which it was ordered that before any of the expenditures authorized in the appropriations of that year for lighthouses should be made, "The board of navy commissioners shall cause an examination to be made for the purpose of ascertaining whether the safety of navigation required any additional facilities, and if so, what is most suitable for each place, and to report their opinion in regard to all such places to the secretary of the treasury, who should proceed with the work recommended; and that if the board should advise that the improvements were not needed, they should not be made, and the commissioners' opinions with the facts should be reported to congress."*

The navy commissioners detailed twenty-two officers to this duty, who made their reports to the board in time to have them embodied in a report by the board itself to congress in the same year. This report arrested the building of thirty-one proposed lighthouses, which in the opinion of the board were considered unnecessary. The navy commissioners concluded their report by suggesting that some "additional measures are desirable for obtaining the necessary information to secure the greatest public advantage for the expenditures which may hereafter be authorized for these purposes."

The report received marked attention by congress, and on the report of the committee on commerce in the senate, to which the subject had been referred, it was enacted, July 7, 1838, "in order that congress may be furnished with more exact information in regard to lighthouses and the lighthouse system, the president is hereby authorized to divide the lake and Atlantic coasts into such districts as he

*The following extract from a letter of the fifth auditor, dated March 10, 1841, to the collector of the port of New York, in which he requests him to issue proposals for the purchase of oil for the lighthouses in his district, will show the primitive method of the establishment in vogue at that time: "The oil of both kinds (summer and winter strained) should be tried by burning a few nights before it is received. Some of the officers of customs could do this at their dwellings and determine the quality of that offered."

may deem expedient; and he shall appoint a naval officer or officers, if the public service will allow of it, to survey and examine each district with reference to all the objects aforesaid; and it shall be their further duty to inspect all the lighthouses, light-boats, beacons, buoys, etc., and to report upon their present condition and usefulness; also to inquire and report whether the present public emergencies require any, and if any, what further additional works and improvements of the above description, and of what kind; and also further to report whether in their judgment the public interest requires any modification of the system of erecting, superintending and managing the lighthouses, light-boats, etc., and if so, in what particulars; and each board shall report separately on all these matters, which reports shall be laid before congress." Under this comprehensive act the Atlantic coast was divided into six, and the lakes into two districts, and an officer of the navy detailed to each. Elaborate reports were made by them, which were practically a severe reflection upon our system, and showing a much needed change. The first forward move was made in August of the same year, when Captain Matthew C. Perry, under authority of the treasury department, and by order of congress, expressed in another portion of the act just mentioned, purchased of Lepaute, Paris, two sets of Fresnel lens apparatus, which were erected after much delay at the Highlands of Navesink. Captain Perry also made a very interesting report on the lighthouse systems of England and France, which was published in compliance with a resolution of the senate of July 20, 1840.

The public mind had become educated on the subject beyond that of the authorities in charge of the establishment, and complaint, inquiry and explanation became more and more frequent. If Mr. Pleasanton was satisfied, the secretary of the treasury was not; and at the latter's request in 1842 an appropriation of $4000 was made, under which Mr. I. W. P. Lewis, a civil engineer of eminence, was commissioned by Mr. Forward, then secretary, to inspect and report upon the condition of the lights and lighthouses of our coast. His report of his inspection of seventy lights, published in 1843, in compliance with a resolution of the house of representatives, was a most scathing showing of inefficiency, and had the effect of raising such an opposition and clamor on the part of those interested in the retention of the existing state of things, that his inspection never went farther. The fifth auditor, in a letter of Jan. 3, 1844, to Mr. Spencer, Mr. Forward's successor as secretary, speaks of the "lighthouse estab-

lishment and its management in the states of Maine, New Hampshire, and Massachusetts having been grossly misrepresented by a man (I. W. P. Lewis) employed by your predecessor to inspect the same." These representations, in spite of the protestations of the fifth auditor, were fully borne out by later boards, which show Mr. Lewis to have acted in the most honest and fearless manner; that the construction of the lighthouses was of the rudest and most blameworthy description; that the work had been slighted in every possible way by the contractors; that, for instance, the three lighthouses at Nauset on Cape Cod, built of brick, had no foundation whatever, being built directly on the surface of the ground, and that the inner and outer courses of brick-work had been filled in with loose bricks, stones and sand. To quote his words: "The lanterns containing the lamps and lantern reflectors are by far the most curious parts of the lighthouse establishment. They are all on one uniform model, differing only in magnitude—octagonal on the plan the height of the sides being about equal to the diameter at the angles. The frames are very ponderous, of wrought iron, and containing by a fair estimate three times the quantity of material requisite. The angle-posts are two inches square, and with the sashes attached, the width of the angles is increased to four inches; the sash bars are one inch wide, and the glass mostly 10×12 inches square (excepting a few fitted up quite recently, which were copied from the improvements made at Boston light), and of the most impure kind, full of striæ and veins, so that what light escapes from its iron cage is refracted in all directions by the effect of the glass, and but a small portion reaches the eye of the observer." He also found the reflectors of various and irregular shapes, badly made and badly kept; the lamps were in equally bad condition; the want of care by the keepers and the inefficiency of the buoyage, &c., were also shown.

This report, made by a man who evidently had knowledge of the subject, was the cause of a most acrimonious discussion, and the result was that in 1845, Lieutenants Thornton A. Jenkins and Richard Bache of the navy were detailed, at the request of the secretary of the treasury, the Hon. R. J. Walker, to examine and make a report upon the lighthouse systems of Europe, so that there might be some definite means of comparison between our own system and those abroad. The report of these officers, dated June 22, 1846, was elaborate and exhaustive, and its recommendations contain the germ of our present lighthouse organization.

In appropriations for the service in 1849, it was provided that "in all cases where preliminary surveys are necessary to determine the site of a proposed lighthouse or light-boat, or to ascertain more fully what the public exigency demands, the secretary of the navy shall thereupon appoint one or more officers of the navy, not under the grade of commander, to perform the required service; or when the expenditure is to be made under the direction of the bureau of topographical engineers, the secretary of war shall appoint one or more officers of the corps of topographical engineers, possessing the requisite skill and experience to perform like service." The army engineers had been employed on occasional works of exceptional difficulty since 1838, and the act regarding appropriations of 1847 particularly mentioned six constructions of this class which should be built under the superintendence of the topographical bureau.

The reports of Lieutenants Jenkins and Bache, and of the other naval officers who under the several acts mentioned had examined the lighthouses of the coasts and lakes, had as result the passage of secs. 8 and 9 of the act for the appropriations, &c., for lighthouses, approved March 3, 1851, that "The secretary of the treasury is hereby authorized and required to cause a board to be convened at as early a day as may be practicable after the passage of this act, to be composed of two officers of the navy of high rank, two officers of engineers of the army, and such civil officer of high scientific attainments as may be under the orders or at the disposition of the treasury department, and a junior officer of the navy to act as secretary to said board, whose duty it shall be, under instructions from the treasury department, to inquire into the condition of the lighthouse establishment of the United States, to make a general detailed report and programme to guide legislation in extending and improving our present system of construction, illumination, inspection and superintendence. . . .

"Sec. 9. And be it further enacted, that the president be and he is hereby required to cause to be detailed from the engineer corps of the army, from time to time, such officers as may be necessary to superintend the construction and renovating of lighthouses."

This board was composed of Commodore Shubrick, U. S. N., Commander Dupont, U. S. N., General Totten, U. S. corps of engineers, Lieut. Col. Kearney, U. S. top. engineers, Professor Bache, superintendent of the coast survey, and Lieut. Thornton A. Jenkins, U. S. N., secretary.

The board made its report Jan. 30, 1852. It was published in a volume of 760 pages, and, says the N. Y. Journal of Commerce of

July 9, 1852, "embodies all the scientific and practical information necessary to the clear understanding of this branch of the public service, hitherto so shamefully neglected and viciously managed. . . .

"In the report just published by the board, who are individually and collectively beyond the merest suspicion of prejudices or bias of any kind, the array of facts is so strong, the deficiencies pointed out are so numerous, and the glaring inconsistencies so clearly held up to view, that the wonder is how such a gigantic system of abuses could so long have escaped discovery and a speedy extermination. And yet the details are for the most part a repetition, on an extended scale however, of the very defects pointed out first by Messrs. Blunt, next by the board of naval officers in 1838, and thirdly in a more explicit and technical form by Mr. Lewis in 1842."

The report of the board was conclusive: it showed an absolute want of system of construction, illumination, inspection and superintendence, and that the whole was about as bad as it well could be. Many pages are taken up by a bare enumeration of defects, and the language quoted from the journal mentioned is none too strong in the light of the report. As an instance, the report states that no argand burners and no reflectors were found at the Sandy Hook light-vessel; all the light-ships were in very bad condition; in two instances they were nearly deserted; in one case both keeper and mate were absent, and in the other there was no one on board but a colored boy of twelve or thirteen years. "Nothing," to quote the report itself, "could be much worse than the floating lights of the United States."

The fifth auditor, in a communication to congress, attempted a rebuttal of the board's statements, but in a reply dated May 7, 1852, the board showed the ludicrous inaccuracy of the effort. The final result was the passage, against much opposition on the part of obstructionists, whose names should be held in remembrance, of the act approved Aug. 31, 1852, by which the president was required to appoint two officers of the navy of high rank, one officer of the corps of engineers of the army, one officer of the corps of topographical engineers of the army, and two civilians of high scientific attainments whose services may be at the disposal of the president, and an officer of the navy and an officer of engineers of the army as secretaries, who should constitute the lighthouse board, of which the secretary of the treasury should be *ex-officio* president. The topographical engineers being shortly afterwards merged in the engineers, both of the engineer officers were appointed from this latter corps, and with this exception

the above is the board of to-day. The law also required that the coast of the United States, including the lake coasts, should be divided into not more than twelve districts, to each of which an officer of the army or navy should be assigned as an inspector, subject to the orders of the lighthouse board, and that such officers as are necessary to superintend the construction and renovation of lighthouses should be detailed from the engineer corps of the army.

The board is required to elect by ballot one of its members as chairman, who shall preside at the meetings when the president is absent; it is also required by law to meet for the transaction of business on the first Mondays in March, June, September, and December, but may be convened whenever the exigencies of the service may demand it. In the intervals the business, under the rules established by the board, is transacted by an executive committee consisting of the chairman and the two secretaries. Both this law of 1852, establishing the board, and that creating the temporary board of 1851, were drafted by Lieutenant, now Rear Admiral, Thornton A. Jenkins, no modification of the original draft being made other than to reduce the proposed number of districts from eighteen to twelve.

The first board of the new organization was as follows: The Hon. Thos. Corwin, secretary of the treasury, president *ex-officio;* Commodore Wm. B. Shubrick, U. S. N.; Brevet Brig. General J. G. Totten, U. S. corps of engineers; Commander S. F. Dupont, U. S. N.; Lieut. Colonel James Kearney, U. S. corps topographical engineers; Prof. Alex. D. Bache, superintendent coast survey; Prof. Joseph Henry, secretary of the Smithsonian Institution; Lieutenant Thornton A. Jenkins, U. S. N., naval secretary; Captain E. L. F. Hardcastle, U. S. corps top. eng., engineer secretary.

The board met for the first time in Washington, Oct. 9, 1852, and Commodore Shubrick was elected chairman. It found a gigantic work before it: nothing less, as it has turned out, than an entire reconstruction of towers, dwellings, and apparatus. There were, upon the assumption of their duties, classed according to actual value: one first class or primary sea-coast light; two second class or secondary sea-coast lights; sixteen third class or bay, sound, lake coast, &c., lights; eighty-seven fourth class or bay, sound, river, and harbor lights; two hundred and sixteen fifth and sixth class or river, harbor and pier-head lights; a total of three hundred and twenty-five. Of these but five had Fresnel apparatus. In addition there were thirty-four light-vessels and (about) twenty-six hundred buoys and beacons.

The following comparison will show the speed with which the establishment had grown.

Date.	No. of Lighthouses.	No. of Light Vessels.
1789	8	0
1820	55	0
1838	210	28
1852	325	34

By the report of the lighthouse board of 1880, there were on July 1 of that year: First order lights, 47; Second order lights, 26; Third order lights, 65; Fourth order lights, 204; Fifth order lights, 128; Sixth order lights, 160; Range lenses, 10; Lens lanterns, 14; Reflectors on lighthouses, 10; Stake lights on rivers, 819; Light ships, 31; Whistling buoys in position, 25; Other buoys in position, 3115; Fog signals, steam or hot air, 57.

This shows a total of six hundred and ninety-five lighthouses and light-vessels, besides the eight hundred and nineteen stake lights, used chiefly on the Mississippi, Missouri, and Ohio rivers. These last were established under a law of June 23, 1874, and have proved of the greatest aid to the commerce of these great highways.

The magnitude of the work done by the lighthouse board since 1852 is shown by the fact that of the three hundred and twenty-five lighthouses turned over to them by the fifth auditor, *all but seventy-one* have been completely rebuilt, and all have been repaired and refitted without exception. This has been done, of course, with vast labor and at large expense; the latter, however, was not as great as might be supposed, as the expense of replacing the reflector lights in the then existing stations by lenticular apparatus was more than covered by the saving in oil.

The coast and lakes were divided into twelve districts, in which there has been but little change, except to add the two districts of the Missouri and Mississippi and the Ohio. The extent of these districts is as follows:

The First from the NE boundary of Maine to Hampton harbor, New Hampshire.

The Second from Hampton harbor to Gooseberry point, Massachusetts.

The Third from Gooseberry point to Squam inlet, New Jersey, including Hudson river and lakes Champlain and Memphremagog.

The Fourth from Squam inlet to Metomkin inlet, Virginia.

The Fifth from Metomkin inlet to New River inlet, North Carolina.

The Sixth from New River inlet to cape Canaveral, Florida.

The Seventh from cape Canaveral to the Perdido river, near Pensacola on the west coast of Florida.

The Eighth from Perdido river to the Rio Grande, Texas.

The Ninth was merged in the Eighth.

The Tenth embraces all the aids to navigation on the American shores of lakes Erie and Ontario and St. Lawrence river.

The Eleventh includes lakes St. Clair, Huron, Michigan, and Superior, and the connecting straits.

The Twelfth is the state of California.

The Thirteenth is the state of Oregon and Washington Territory.

The Fourteenth extends from Pittsburgh to the mouth of the Ohio.

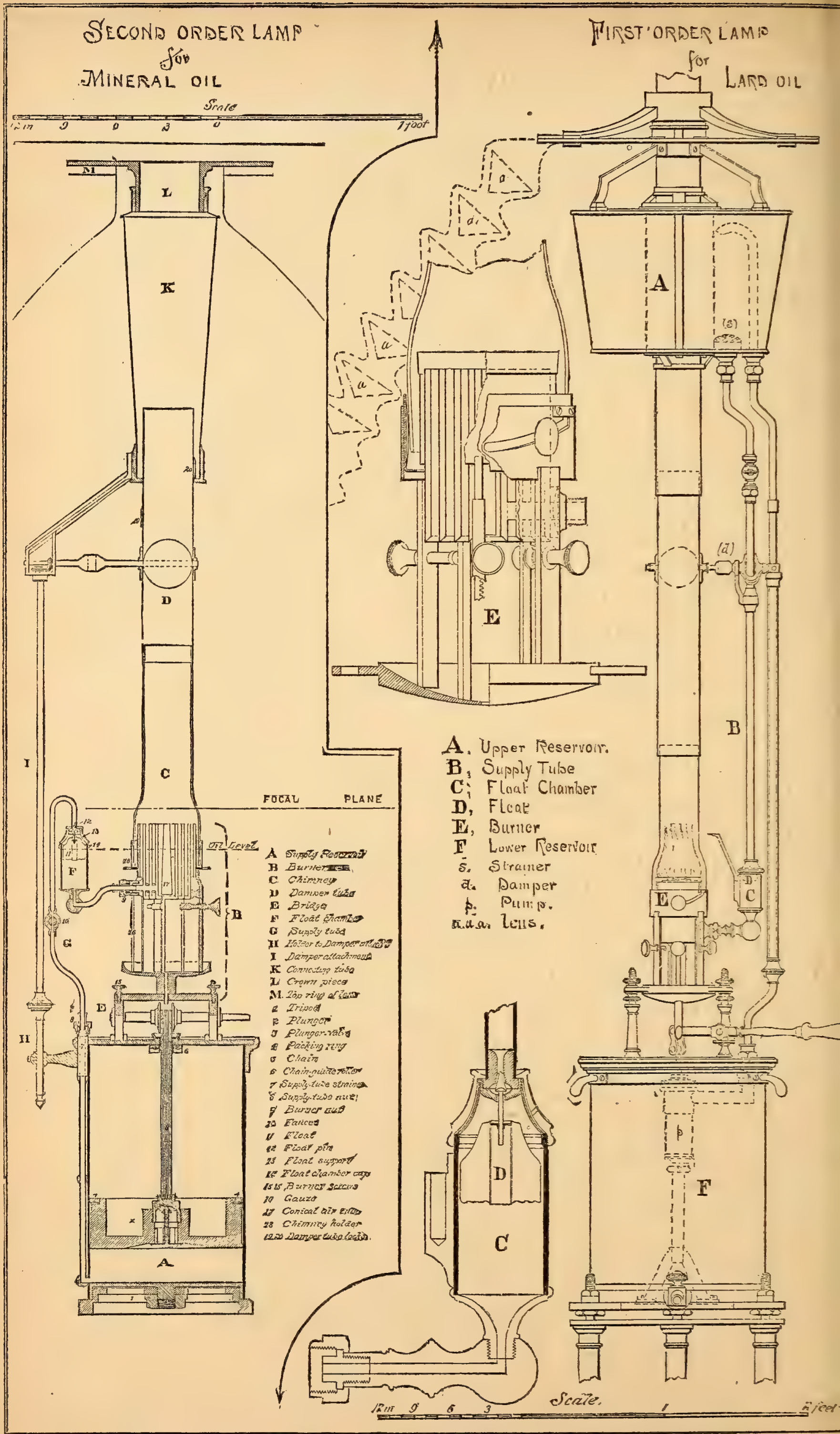
The Fifteenth extends from New Orleans to the head of navigation of the Mississippi and Missouri.

To each of these districts are attached a naval officer as an inspector, who has charge of the inspection, supplies, buoyage, the light-vessels and *personnel* of the district, and an officer of the engineer corps of the army, who has charge of the construction and repair of the lighthouses and dwellings. In the Third district at Tompkinsville, Staten Island, is established the general depot, whence are distributed the supplies of all kinds and the illuminating apparatus. There are here large storehouses for supplies, and a machine-shop in which are manufactured all the lamps used by the establishment, and in which all the lenses are first set up previously to being forwarded to their destination. All oil is here tested before being received as to its illuminating and other properties; every first and second order lamp chimney is likewise thoroughly tested, and a certain percentage of the chimneys of the lower orders. Established in 1860, this depot has grown from comparatively small beginnings to large and important proportions, enabling the establishment, as far as the supply of its more delicate and important apparatus is concerned, to be self-supplying. Mr. Joseph Funck, the foreman of the lamp-shop, is the inventor of the important improvements in the lamps used for the higher order lights, which have made them the most efficient lamps for lighthouse purposes ever invented. Our dependence for some years after the establishment of the present board was upon France. The multiple wick had been invented by Fresnel, and its use was a necessity in lamps of high power, as the intensity of a flame depends not only upon its surface but upon its depth. Various mechanical means were em-

ployed to supply the great amount of oil needed for the support of so large a flame, capillary attraction being altogether insufficient; it was necessary to bring the surface of the oil to the flame itself to prevent the frequent charring of the wick and consequent reduction of the intensity of the light. The favorite French lamp was one in which several small pumps were driven by clock-work, pumping the oil to the required height; some few of these are still in use by ourselves, but the Funck lamp, in efficiency, simplicity, ease of management, non-liability to get out of order, and in cheapness, far surpasses it. The specialty of the lamp is the float which regulates the supply of oil. (See plate I.) In the lard-oil lamps the oil is first poured into the lower reservoir shown in the sketch, and pumped thence into the upper reservoir, whence it descends through the supply tube. The float chamber is placed at such a point that the surface of the oil in this chamber will be at the same level as the top of the burner. This level remains constant through the action of the float, which is lifted by the oil and closes the supply tube when the supply becomes too great. It is thus constantly opening and closing the supply, giving practically a constant level. The draft from the chimney is carried through the upper reservoir, thus keeping the oil warm; a primal necessity in winter, as lard oil congeals at 40° or 45°, and in cold weather must always be heated before it is used. The danger of overheating mineral oil required a modification of this lamp (see plate I), and instead of an upper reservoir from which the oil descends to the float chamber by its own gravity, there is a low reservoir, in which acts a heavy piston, which by its weight forces the oil through the supply tube. The level of the oil in the mineral oil lamp is kept lower than in the lard oil, and it is lifted to the flame by capillary attraction for the distance of an inch and a half, as it will not do to bring its surface in actual contact with the flame. This latter lamp is now rapidly replacing the second and third order lard oil lamps; the entire substitution being expected to take place by October, 1882.

Sperm was the only oil used in this country in the lighthouses until the advent of the present Establishment. Colza, a vegetable oil produced from a species of wild cabbage, largely grown for the purpose in southern Europe, had been adopted in France, and later in England. Olive oil was also used largely by countries where it was produced. The lighthouse board by its desire to adopt the colza oil in this country encouraged the growth of the plant here, and it was soon found that it could be supplied by the home market at a lower

Plate 1.


SECOND ORDER LAMP for MINERAL OIL
Scale
1 foot
FOCAL PLANE
Oil Level
A Supply Reservoir
B Burner
C Chimney
D Damper tube
E Bridge
F Float chamber
G Supply tube
H Holder to Damper attachment
I Damper attachment
K Connecting tube
L Crown piece
M. Top ring of lantern
1 Tripod
2 Plunger
3 Plunger-valve
4 Packing ring
5 Chain
6 Chain-guide roller
7 Supply-tube strainer
8 Supply-tube nut
9 Burner nut
10 Faucet
11 Float
12 Float pin
13 Float support
14 Float chamber cap
15 15 Burner screws
16 Gauze
17 Conical air tube
18 Chimney holder
19 20 Damper tube locks
FIRST ORDER LAMP for LARD OIL
A, Upper Reservoir.
B, Supply Tube
C, Float Chamber
D, Float
E, Burner
F Lower Reservoir
s, Strainer
d, Damper
p, Pump.
a, a, a, Tells.
Scale.
1 feet

price than sperm. It was finally shown, however, after much experiment, that lard oil was an equally good illuminant with colza, and as it could be produced more cheaply, and as the supply was constant, with no fear of failure, it was adopted. This, however, is in its turn being gradually pushed aside by mineral oil: the substitution has taken place first in the lower orders; all from the fourth orders down are illuminated by a capillary lamp with a round wick. The Funck mineral oil lamp has been adopted for the higher orders, but the lard oil has been retained for the first order lights, as though it has been found that the relative power of mineral and lard oil in the two-wick lamp is 78 and 69 candles, and in the three-wick they are about equal (163 candles), that in the four-wick or first order, the flame of this lamp being $3\frac{1}{2}$ inches in diameter, and $3\frac{3}{4}$ inches high in the lard oil burner, the mineral oil has not, as yet at least, given as good results as the lard, being but 342 candles to the 400 of the lard oil, and consequently of course has not been adopted for this class of light. The mineral oil used must have a flash-test of 140° and a fire-test of 164°.

To show the difference between this oil and that sometimes sold, I would state that last winter some oil was tested at the lighthouse depot which was a sample of some which had exploded, burning a woman to death at Tompkinsville; the oil had a flash-test of 68°, or it was ready to explode under the most ordinary circumstances.

The attention of the lighthouse establishment was drawn to the subject of mineral oil as early as 1807, as will be seen by the copy of the following letter addressed to the then secretary of the treasury:

PHILADELPHIA, September 14, 1807.

ALBERT GALLATIN, Esq.

Sir:—We have lately received by our ship the Coromandel, from Rangoon, in the kingdom of Ava, a variety of the curious productions of that interesting country, among others, about five thousand gallons of their celebrated earth oil. It is perhaps the best article known for burning in lighthouses, making a very strong, clear, and bright flame, emitting at the same time a great volume of smoak. We take the liberty of offering it to you for the use of the government in the lighthouses on our coast. The price we would leave until by an experiment (which we request you to give an opportunity of being made and reported on) its actual merit compared with the oil at present in use, can be ascertained.

If you approve of it, Sir, the experiment may be made at cape Henlopen. From the opportunity our son, John B. Davy, commander and supercargo of our said ship Coromandel, obtained of a personal and friendly interview with the monarch of the Burman empire and his family, and of opening a new and very inter-

esting intercourse with the chiefs of the government, some important results may arise to our commerce in the eastern world; on this subject it is our intention soon to make some direct communications to the president of the United States. In the meantime we have no doubt of your disposition to promote our endeavors to obtain consumption for so valuable an article of import as the oil proposed, and any communication that you may favor us with on this subject will be very highly esteemed by,

Sir, your obedient and humble servants,

WILLIAM DAVY & SON.

The text of the reply to Mr. Davy I have not at hand, but it could hardly have been very favorable, as sixty years were to pass before our lighthouses began the use of such oil, though by this time we had come to think the "great volume of smoak" not so desirable a quality as it evidently appeared to the writer of this letter.

An attempt was made to use a gas made from rosin as early as 1844, the experiment being made at the light near Wilmington, Delaware; but the difficulty of guarding against accidents to gas pipes when used within reach of larger gas establishments, and the expense and difficulties attending the manufacture at the station itself, have hitherto prevented any but a very limited adoption. Compressed gas is now used in "ten lights at the northern entrance to Currituck sound, North Carolina. This gas is made and compressed at the board's own gas works, and it is carried to each of the beacons in tanks, built into a scow, which is towed by a steam launch." These lights are kept constantly burning, and burn for ten days; no keepers are at the stations themselves, but the whole work of making the gas from the naphtha, of charging the beacons, etc., is done by three men, who are constantly employed on this duty.

The electric light has of course occupied much of the thought of all lighthouse establishments, and it is now in use in several English and French lighthouses, but it is still a question as to whether there is any special advantage in its use. In ordinary weather the present first order lights can be seen as far as the curvature of the earth will permit; in fog no light can be seen, the sun itself being obscured. As we can never hope to make an artificial light as powerful as the sun, the question of the practicability of furnishing a light which will show through a fog may as well be dismissed at once, and the question as to what kind of light can be seen for the greatest number of hours in the year is the one to be decided, and this is one not so easily answered as one may casually think. The extreme whiteness

of the electric light and its deficiency in red rays seem to be a great defect. Very conclusive French experiments seem to show that such deficiency is fatal to the penetrative power of a light. These experiments, made under governmental supervision, are very striking, especially when it will be remembered that from seventy to ninety per cent. or more of the original white light is cut off by the intervention of the red medium. The following is the official report on this subject:

"Five flames regulated in such a way that four of them being covered with glass colored red of copper, silver or gold, they all appeared of the same photometric intensity observed at 0.80 of a metre distance. The intensity had been fixed at 0.005 of a carcel burner, so that the limits of ranges could be reached without going outside the inclosure of the Champ de Mars, within which the experiments were made. The sky was clear, the night dark, and the observers, four in number, reported as follows:*

"1. *At a distance of five hundred metres the white light ceased to be visible, while the red lights, except the red of gold, were still quite bright.*

"2. At seven hundred and fifty metres the same lights remained visible, but the red light was distinct only in the light which was covered by a glass colored very strongly with copper, its absorption being estimated at ninety-nine one-hundredths of the white light."

Other experiments with more powerful lights were made under the same atmospheric conditions, "but it was always found that the intensity of the red lights diminished much less rapidly than the white as the distance increased." The red of copper in every instance was found superior to that produced by any other metal.

The report of trial in fog is as follows: "The red lights are much superior to the others, because red rays are much less obstructed in their passage through them; the red rays of white lights pass through such fogs, while the others are rapidly absorbed, and green lights, after becoming white, rapidly diminish in intensity. . . . Five reflectors producing white lights of about sixty carcel burners in the axis were observed during fog. The light of the first was uncolored, that of the second red by gold, that of the third red by copper, that of the fourth green, and that of the last blue. All ceased to be visible at a distance of sixteen hundred metres. The color of the red of gold was with difficulty distinguishable at fifteen hundred metres, while that of the red light colored by copper was still well defined. The green

* Illumination and Beaconage of the Coasts of France.

light disappeared at one thousand, and the blue light at five hundred and thirty metres." This is a very extraordinary result, it being remembered that possibly quite eight-tenths of the original light being obstructed by the colored medium, the remaining two-tenths, wholly red, carried as far as the unobstructed white light of five times the intensity. It shows that the primal intensity is not always a surety of farthest range, but that of two given lights the one having the greatest quantity of red rays is best. The lighthouse board has several times asked for an appropriation to make the necessary experiments on a large scale with an electric light, but have heretofore been refused. It is intended, if the request for the fifty thousand dollars needed is granted by the coming congress, to establish an electric light in one of the towers of the Highlands of Navesink lighthouse, where, the two lights of this station being two hundred and twenty-eight feet apart, an excellent base is afforded for comparative experiment; the Sandy Hook lighthouses and the two light-ships off Sandy Hook will afford excellent stations where the observations of intensity and visibility can be made.

The lenticular apparatus known as Fresnel has almost completely superseded the reflector or catoptric system in use before 1852. Six sizes are in general use, designated orders; and as for many years the French were the only makers, the result is uniformity throughout the world for any given order. The great expense of the plant and the great difficulty in obtaining workmen equal to the work have left the manufacture largely in the original hands: and the French firms of Lepaute, Barbier & Fenestre, and Sautter & Co., have almost the monopoly. The great glass firm of Chance Bros., of Birmingham, England, are their sole competitors. (See plates II and III.) The cost for a first order lens varied with flashes is about twelve thousand dollars, this being the most expensive apparatus furnished; the price diminishes rapidly with the size, being for a fixed light of the third order about two thousand, and for a fixed light of the fifth four hundred. Any special means of distinguishing a light by flashes, etc., increases of course the cost largely. On a coast so thickly lighted as our own, the question of distinguishing a light beyond mistake is a most important one, the means being fewer than may be supposed. The colors that may be used are practically reduced to white and red, these being the only ones used in our service, though green is sometimes used for short ranges in other countries. Even red is used in our sea-coast lights

Plate II.

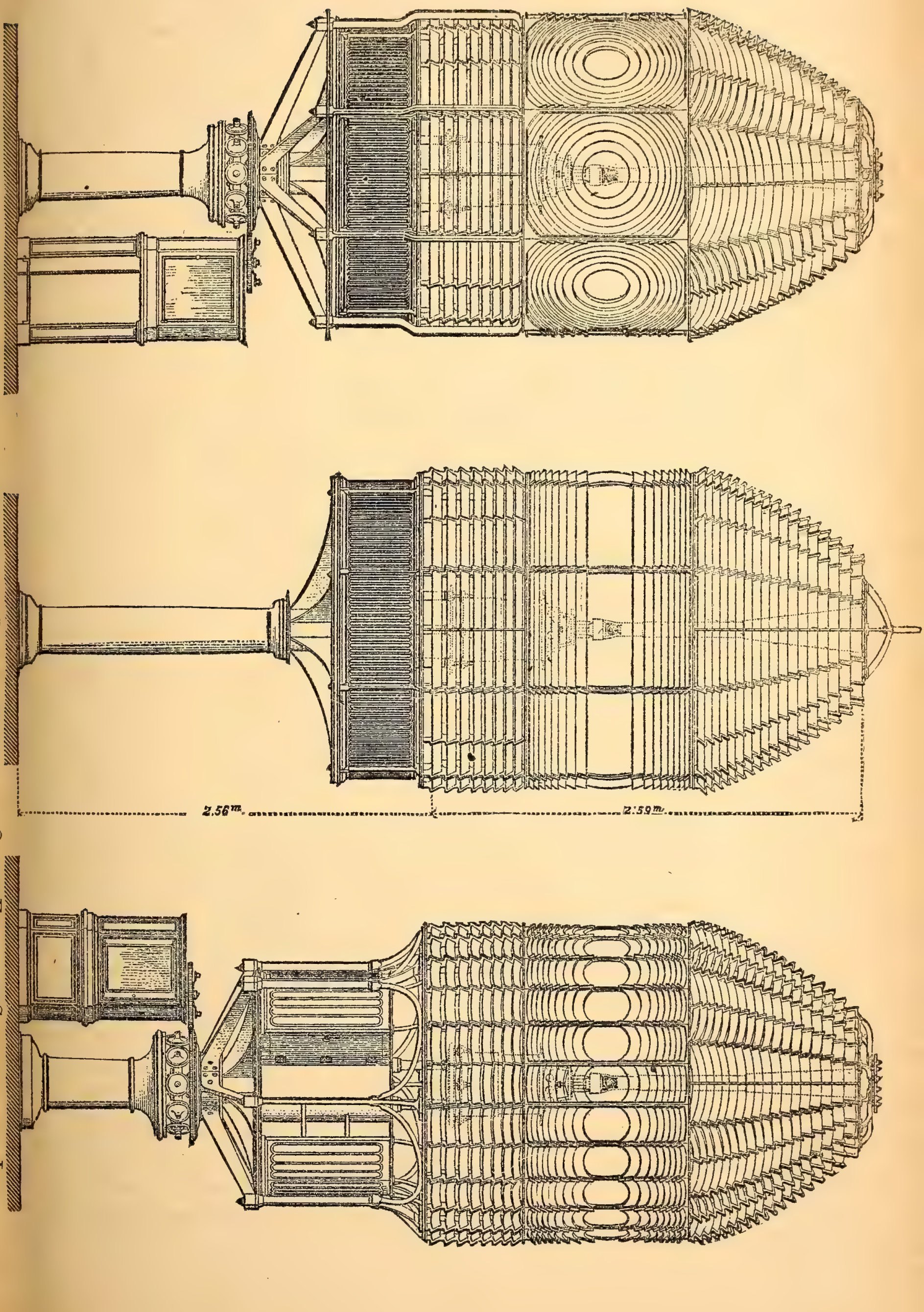
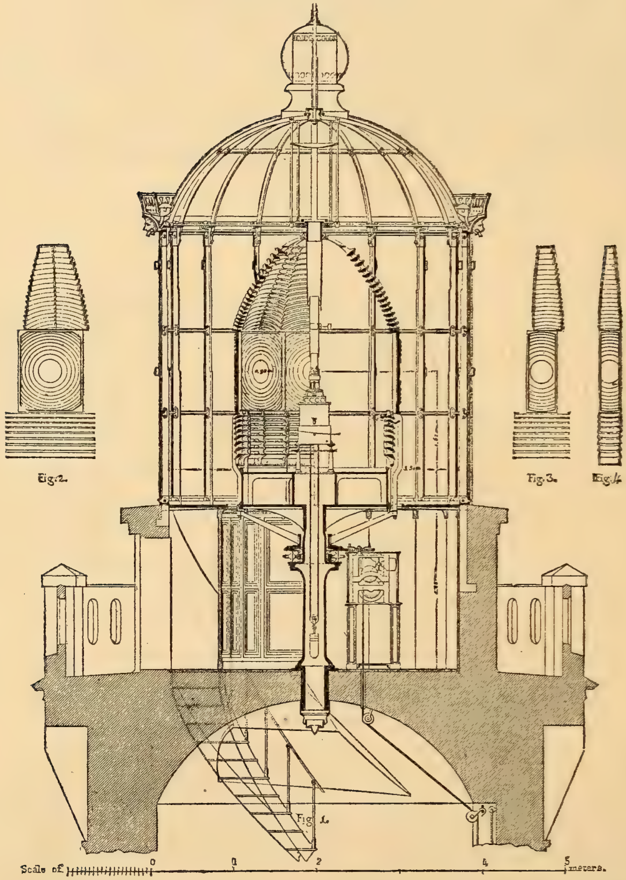


Plate III.



ARRANGEMENT OF LANTERN WITH LENS (FOR FLASHING LIGHT.)

to but a very limited extent, there being but three first order lights where it appears, and this in flashes, where the great increase of intensity by concentrating the beams of light in the flash causes any disparity to disappear. The lighthouse establishment has thus fixed upon the following distinguishing characteristics:

Fixed white; fixed red; flashing white; flashing red; flashing red and white; fixed white varied by white flashes; fixed white varied by red flashes; fixed white varied by red and white flashes; fixed red varied by red flashes; finally, two lights, and in one case three, near together. The name revolving light is discontinued. In the catoptric system there were a number of lamps and reflectors set in a frame which, if the light was fixed, was circular. In the case of the revolving light the frame was made square or triangular, and there was a group of lamps to each face, the number varying with the order. The flash which is substituted for the alternate illumination and obscuration produced by revolving the light itself, is now produced in lenticular apparatus in three ways; first, by sets of prisms with vertical elements which revolve about the central lens; secondly, by inserting in the drum of the fixed light apparatus, annular lenses and revolving the whole lens (these are used for a fixed light varied by flashes); third, by having the whole lens made up of a series of annular lenses, giving in its revolution a series of obscurations and flashes.

In a first order light, the original light of four hundred candle power is increased by the fixed lens (using the determination of the French lighthouse authorities) to ten thousand candles, and the flash prisms multiply the original intensity in some cases as much as three hundred and thirty times, producing thus a flash with an intensity of one hundred and thirty-two thousand. Color is given in lights which show only the one color, by a colored chimney; in cases of white lights varied by colored flashes, a colored panel is made to revolve about the exterior of the lens in connection with the flash panels. This interesting subject of the construction of lenses is fully discussed by Stevenson in his "Lighthouse Illumination," in which are given the formulas for the determination of the radii, etc., of the generating arcs, and I would refer any one interested in the subject to this book.

The general principle adopted by the board on its organization was that sea-coast lights of the first order should be placed at such intervals along the whole extent of the coast, that as a rule one light should not be lost sight of until another is made. We thus have the

great lights of Gay head, Block island, Montauk, Shinnecock, Fire island, etc., with a continuous intersection of lights of this class as far as cape Hatteras. East of Gay head the first order lights are not so numerous, there being, however, a continuous intersection of lights of a lower order. South of Hatteras the circumstances of the coast-line are not such as to demand the multiplicity of lights which is required further north: St. Augustine, cape Canaveral, Jupiter inlet and Fowey Rocks lights, on the eastern coast of Florida, being placed at intervals of about ninety miles; but in the next one hundred and eighty miles, in rounding the Florida Keys, there are found no less than seven lights of the first order. The extension of lights on the Pacific coast has followed the necessities of the case in the same manner. Most of the great headlands are lighted, and lights are multiplied wherever the needs of commerce demand it. Here, however, as on the eastern coast of Florida, the long stretches of coast-line without a break in which is a harbor or port, render such intervals as eighty or ninety miles between coast-lights not uncommon. It is the intention, however, to increase the number of lights on this coast as soon as the appropriations can be obtained.

It will thus be seen that our coast may be regarded as perfectly lighted; there being no part of it which is frequented on which the navigator in approaching it can find himself out of sight of a lighthouse. The difficulty has been to avoid too great a multiplication of lights due to local necessities, such lights being aids to those constantly using these points, but confusing to the general navigator less accustomed to them. There are in sight from one point in Nantucket sound fifteen, and from a point in Long Island sound thirteen lighthouses and light-vessels.

The almost entire reconstruction of the stations built before 1852, and the addition of the great number since, have involved some of the most difficult examples of lighthouse engineering known. The simple plan of having four classes of towers, sixty-five, fifty, forty and thirty feet high, was soon discarded, and the lighthouse was suited to its locality. Minot's ledge lighthouse, built of granite to replace a pile structure erected in 1848 and destroyed in a gale of 1851, was completed in 1860 at a cost, including the keepers' houses ashore, of $300,000, and offers one of the best examples of modern lighthouse engineering, there being none which offered greater difficulties. Spectacle Reef lighthouse, built on a reef in lake Huron ten and a half miles from shore, is also of granite, and was completed in 1874 at a cost of

$375,000. Fowey Rocks lighthouse, a first order light on the coast of Florida, may be cited as an example of the iron-pile system of lighthouse, an application of which has been extensively made on our southern coast. Many of our large towers are of brick, as Shinnecock, Fire island, and others farther south. Iron has also been extensively employed, especially in lighthouses of the smaller class; but there are several of the largest class of this material, conspicuous amongst which is that newly built at cape Henry, with a height of one hundred and sixty-five feet.

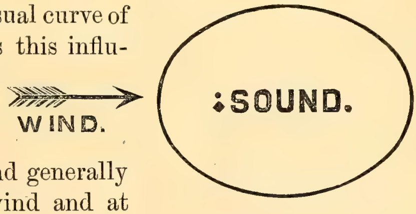
Though one would think that we had nearly perfected our system of lights, especially on the coast from New York eastward, there is still a constant addition to the number, and there are at the present moment three building in the Third district alone, and also two others which have just been completed and lighted.

The light-vessels are from 200 to 400 tons, differing in size according to the varying conditions in which they are placed. They are still using the reflector light, the lamp being a constant level lamp using mineral oil. There are no light-vessels in this country with other than fixed lights, though their use is not unusual in England and in northern Europe. There are eight lamps and reflectors in each lantern, there being two lanterns in use generally to each vessel, though occasionally there is but one. The crew consists of a keeper and an assistant, with from four to six men, one of whom is a cook. In case of being fitted with steam fog signal apparatus, two engineers are added to the complement. They are supplied with rations by the establishment, and the men receive the pay of $25 per month. Much difficulty is experienced in securely mooring those vessels exposed to the full sweep of the sea; a position in which most of them are, the most distant from shore being that on New South shoals, 27 miles from Nantucket. Mushroom anchors of from 3600 to 4800 lbs. are used, usually backed by a smaller one. They are generally moored with forty-five fathoms of chain on each leg of the bridle, and ride to a scope of chain accommodated to the weather. The greatest care, however, will not always insure their permanency, and scarcely a winter passes without the breaking adrift of one or more, several days sometimes passing before their recovery. Being schooner-rigged, the masts for the sails being fitted abaft the lantern masts, they have usually shown that they are able to take care of themselves when driven to sea, and have generally found their way to port without assistance.

Of equal importance with the lighting of the coast are the buoyage and fog signals; indeed, this last, in a climate such as ours, where fogs prevail to such a great degree, may be considered of primal importance, taking rank as a necessity almost before the lights themselves. In the efforts to perfect the systems of signalling in fogs, the lighthouse establishment of the United States stands pre-eminent, more having been done in this country to further this object than in any other. In respect to this we occupy the position which the French establishment has held in relation to lights. The means now employed are bells rung by clockwork, bell-buoys, hot-air trumpets, steam sirens, steam whistles and automatic whistling buoys; all these are of comparatively very late adoption, the bells rung by clockwork coming first. Daboll's trumpet, worked by blasts of air, was adopted in 1855, and is widely used, especially at stations where it is difficult to get a good water supply. The air used for the blasts was formerly compressed by horse power, but hot-air engines of the Ericsson type are now used generally. This trumpet, which in one of the first class has a length of seventeen feet, and a steel reed ten inches long, two and three-quarters wide and an inch thick at the fixed end, was, until the introduction of the steam siren, the most powerful fog-signal known. The latter, however, has superseded it where an intense and far-reaching sound is specially desirable, and where the water supply will admit of its use. It is worked with a steam pressure of from fifty to sixty pounds, a locomotive boiler being generally used for the purpose; the whole of the machinery, as in the case also of the Daboll trumpet, being in duplicate, in case of accident to that in use. The ordinary steam whistle is also largely used, and by some experts is preferred to any other means of signalling in fog. The whole subject of fog signals is an extremely intricate one, and the laws governing their audibility as yet very imperfectly known. The vagaries of sound are beyond the belief of one who has not experimented in the subject, and the most opposite opinions of the laws governing the action of sound have been held by such authorities as Professors Henry and Tyndall. There can be but one absolute rule formulated for the navigator's guidance, and that is, that he must not expect *surely* to hear a fog signal, no matter how near he may be to it. A signal has been inaudible at one time at a distance of half a mile, which at other times has been heard in the same direction fourteen. There may also be intervals of inaudibility, the sound skipping a space of one or more miles and reappearing at a much farther point in the same direction. I have seen

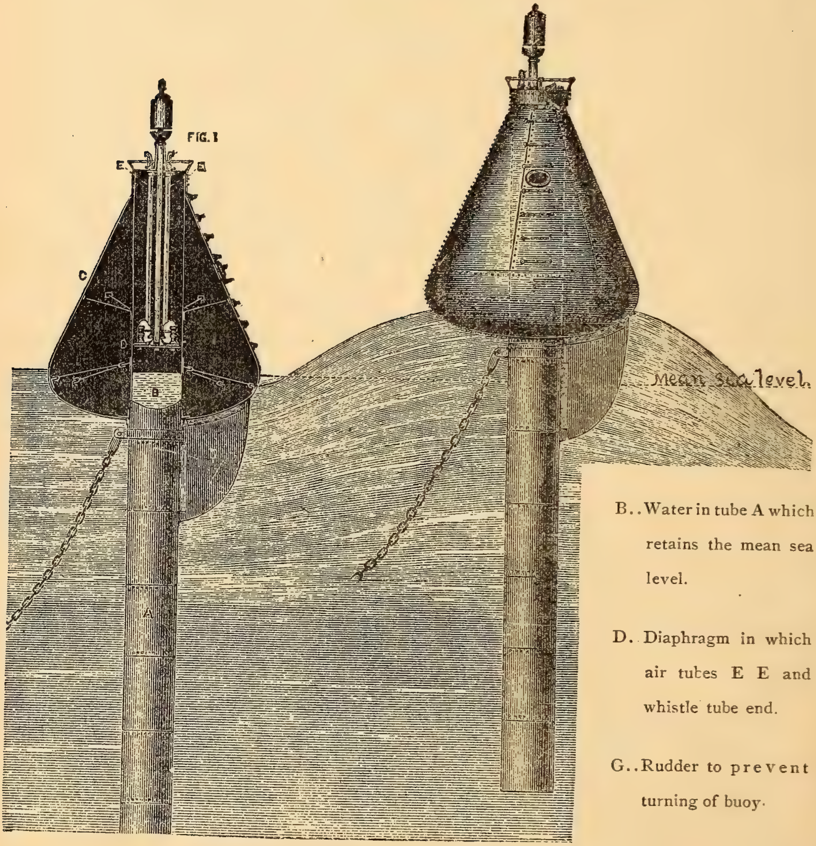
at a distance of half a mile the steam rising from the mouth of the steam siren, which I knew to be working with a steam pressure of fifty-six pounds, and not a murmur of a sound be heard.

Very extensive experiments have been carried on by the lighthouse board in this country, and by Professor Tyndall at the instance of the Trinity board in England. Prof. Tyndall ascribes the inaudibility chiefly to a flocculence or non-homogeneity of the atmosphere. Prof. Henry lays greater stress upon the direction of the wind. It certainly appears that the sound is *generally* heard better down the wind than against it, the accompanying figure representing what may be taken as the usual curve of audibility. Why the wind has this influence has not yet been explained in any satisfactory way. I think, however, that experiment leaves no doubt that sound generally can be heard better down the wind and at right angles to its direction than against it. I use the word generally advisedly, as there are remarkable instances of the reverse of this. In spite of the usual impression, an impression which held even amongst the best informed until lately, fog and snow have of themselves no important influence upon the transmission of sound. *Under no other circumstances is sound so transmissible on our coast as in a northeast snow storm.* Signals rarely audible at much shorter distances are then heard frequently from seventeen to nineteen miles *dead to windward,* and it seems that they are then heard better to windward than to leeward, though upon this last point the evidence is not clear. The only reason that has been assigned for this extreme transmissibility is that the atmosphere must be rendered perfectly homogeneous by the particles of falling snow. Calms or light airs are treacherous; be not deceived by the stillness of the atmosphere or the smoothness of the sea, which seem to render it impossible that the signal could not be heard if working; it is at this very time that its audibility is least certain; and in the driving snow storm, when it would seem to one that it would be most obstructed, it sounds with the greatest clearness and with the least uncertainty.



No more important addition has been made in late years to aids to navigation than the whistling buoy, invented by Mr. J. M. Courtenay, formerly of the East India Company's service, but for many years a citizen of the United States. (See plate IV.) The idea underlying the

Plate IV.



B..Water in tube A which retains the mean sea level.

D..Diaphragm in which air tubes E E and whistle tube end.

G..Rudder to prevent turning of buoy.

invention first came to him by observing that the water in the interior of a steamer's smoke-pipe which was being hoisted on board at the cape of Good Hope, remained at a comparatively constant level whatever the motion of the sea about the exterior. Thus when the buoy rises with the sea there is a large air space in the cylinder to be filled with air from without; when the buoy begins to fall, the valve attached to the tube permitting the ingress of air is closed, and the air is forced out through the whistle, which is an ordinary one, such as is used for steam whistles. The whole is of extreme simplicity, with very little liability to get out of order; the chief trouble arising from the bending of the whistle by being struck by vessels. Very often too, strange to say, the whistles are used as targets by passers-by, and marks of bullets are frequently found upon them, a marked proof of a widely distributed want of moral sense, as nothing could be more purposeless or could be more fraught with danger to the navigator. These buoys have been widely adopted elsewhere throughout the world: they answer their purpose admirably, are a good day mark, and an excellent guide in fog, their sound having been heard under favorable circumstances over fifteen miles. The sea is rarely so motionless that their sound may not be heard at a considerable distance.

Endeavors have also been made to show an electric light on buoys which were to work a dynamic machine on the same principle that the whistling buoy does its work; the only experiment that has been made, however, has thus far been a failure. The Pintsch buoy, which contains a reservoir of gas made from fat, has been more successful. The buoy is charged with gas at a pressure of six atmospheres, and will burn continuously, according to its size, from thirty to one hundred and twenty days. It is provided with a regulator, which is a necessity for giving a flame constant in size, and is fitted with a small lenticular apparatus. One was placed by the company as an experiment near the Wreck of Scotland light-vessel during the past summer, and seemed to work well. Several are in use by the Trinity board of England.

The buoys just spoken of are light and sound signals, rather than day marks. Of these last we have over three thousand, marking almost every hidden rock and danger in navigable waters along our coast. Every wooden buoy is changed yearly, and every iron buoy twice a year; this involves an immense labor on the part of the tenders, and is one of the most important parts of the duty which they perform. The buoys when taken up are scraped, dried and repainted, ready for relaying. The greater number, of course, are wooden spars,

differing in length according to the water in which they are placed, some having a length of sixty feet. The use of these in southern waters is discontinued on account of the destruction by worms, and they are there entirely replaced by iron buoys, which are also used in northern waters to mark the more important points. There are three classes of these, the first having a diameter of six feet and a height of nine feet six inches; the second, four feet four inches by seven feet; the third, three feet two inches by four feet ten inches high. The cost of a first class buoy with its appurtenances is about five hundred dollars. In placing the can or nun buoys, there is a large iron ball, weighing eleven hundred and fifty, four hundred and seventy, and ninety-five pounds, according to class, attached to keep them upright. The first class are usually moored with seven and a half fathoms of one and a half inch chain and a stone sinker of four thousand pounds. These sinkers afford the best and cheapest moorings for buoys that can be used; there is a hole drilled through them through which is run an iron bar with an eye in one end, the bar is simply bent on the under side, and the mooring is ready for use, costing but about nine dollars complete. The life of a chain cannot be reckoned at more than eighteen months or two years; the attrition on those links suspended near the bottom is greatest, the parts on the bottom itself and near the buoy being comparatively little injured, excepting by the natural rust which takes place. Wooden spar buoys are much damaged, frequently by steamers; a fortnight rarely passing in the Third district, for instance, without the necessity of relaying a buoy which is broken short off by a paddle wheel or cut by a screw. The iron buoys are steadfast, excepting in moving ice; during the last winter, buoys to the value, with their appendages, of ten thousand dollars were carried to sea from New York harbor and bay, very few of which were ever recovered. One found its way to Turk's island, one was brought into Madeira by a vessel which picked it up not many miles from the island, and others were sighted at various points and reported. Some years since one drifted into Cork harbor, which was presented to the Irish lighthouse board, and is now moored on the Irish coast. Of course the direction of their travels is not wholly due to the currents, as they expose a very considerable surface to the wind. Some experiments have been made with spar shaped buoys, made of iron, and it may be practicable to make a buoy of this material and shape, larger than the ordinary spar, which will resist the ice. It was not until 1850 that congress established by law a syste-

matic method of painting and numbering buoys; red buoys thus mark the starboard side of the channel coming from seaward, and black the port; dangers and obstructions having a channel on either hand are marked with black and red horizontal stripes; and mid-channel buoys, to be passed close to, are marked with vertical black and white stripes. The buoys are numbered from the seaward end of the channel, the black bearing the odd and the red the even numbers. If there is a branching channel, as say the Passaic river, which with the Kill von Kull enters New York bay on the north side of Staten island, the numbers begin anew at the mouth of this channel. All buoys marking prominent points are marked with the name.

The *personnel* required to carry on the service of all the foregoing is of course very large. To each district there are generally attached two steamers for the inspector's and engineer's work, which carry supplies, attend to the buoyage, and are used in making the inspections. There is now a total of twenty-three steamers and three schooners in the service; to each of the steamers there are ordinarily a master and mate, two engineers, two firemen, a crew of six others, and a cook and steward. The number of keepers at a light varies in number with its importance and position, from one to three and sometimes four. There are one thousand one hundred and forty keepers, besides those on the Mississippi, Missouri, and Ohio, who cannot number less than five hundred. The salaries of these keepers vary from one thousand dollars to one hundred; the greater number being between four hundred and six hundred. The smallest pay is given to the keepers of stake lights and lighted beacons, which only require such time in attending them as can be easily given by a man who keeps up his ordinary occupation. The keepers of all lighthouses are well lodged; have boats where the situation renders boating necessary, and are supplied with libraries, which are contained in neat cases, holding about forty volumes, which are exchanged from time to time as desired by the keeper. Keepers may, upon a vacancy occurring, be promoted from one station to another, and it is the aim to make their positions tenable during good behavior. The final vacancy, which occurs after all changes or promotions have been made which may occur from a death or resignation, is filled by nomination by the collector of the district in which this final vacancy occurs. The nominee receives an acting appointment, which is changed to a full appointment after an examination and a report by the inspector that he is efficient.

The estimates of the lighthouse board for the coming year amount to about 2,700,000 dollars; the increase being chiefly due to the pro-

posed building of some new first order lights on the Pacific coast. The expenditure of this sum, which is made with the utmost economy and care, is an absolute necessity for a proper lighting of the coast and guarding navigation; the lighthouse board, instead of seeking to increase its expenditures, has ever since its establishment acted with the utmost conservatism, has resisted the building of lighthouses, unless in its judgment such a light was necessary. The best means known for lighting, for signalling in fogs, and for marking shoals and channels, are employed of course in every case irrespective of expense, as this is only what is demanded by humanity, but the expenditure has not more than kept pace with the vast traffic which it aids. Our government from the outset has made this expenditure to be borne by the national treasury, nothing being exacted from any vessel of any nationality in return for the benefit given, excepting for a short interval dating from 1804, during which a light duty of fifty cents a ton was levied on foreign shipping. This principle was far in advance of that held by most European powers until within a few years, and even now the entire expenses of the lights of Great Britain and Ireland are borne by the shipping using their ports.

The following table shows the comparative cost of our establishment from the beginning:

Year.	No. of lights and light-vessels.	Cost of support (buoyage, &c., included).
1791	10	$ 22,000
1805	28	93,451
1820	55	244,000
1835	201	382,000
1850	345	633,401
1860	472	729,386
1870	561	1,447,007

The board's estimates for 1880 were for:

Salaries of keepers of lighthouses	$ 585,000
Expenses of light-vessels	250,000
Expenses of buoyage	325,000
Expenses of fog signals	60,000
Inspecting lights	4,000
Supplies of lighthouses	375,000
Repairs of lighthouses	400,000
Lighting and buoyage of Mississippi, Missouri and Ohio rivers	150,000
Amount carried forward	$2,149,000

Amount brought forward	$2,149,000
Expenses of day beacons	25,000
Survey of lighthouse sites	10,000
Fog signals on light-ships	15,000
Steam tender for Atlantic coast (new)	55,000
For building four new light-stations	169,000
For experiments with electric lights	50,000
For other purposes	2,925
Total	$2,475,925

The Lights of Great Britain and Ireland.

The lights of the United Kingdom are under an intricate and cumbersome management, the legacy of an antique system, which a too conservative spirit has prevented discarding in spite of the frequent endeavors of the last forty years.

The Trinity house, subject in some degree to the authority of the board of trade, has the general superintendence and management of all lighthouses, etc., in England, Wales, the Channel islands, Gibraltar and Heligoland, except those which are under local authority; which last, however, are also subject to its inspection.

The commissioners of the northern lighthouses, subject in some matters to the control of the Trinity house, and the ultimate control of the board of trade, control in Scotland and the Isle of Man.

The Ballast board of Dublin have similar authority in Ireland.

These general authorities may levy dues, or, with the consent of the Queen in council, may exempt from dues, alter mode of collection, or substitute other dues.

In all cases of altering, building or removing lights, or placing or removing beacons or buoys, the Scotch and Irish boards must have the consent of the Trinity board; any case in dispute is carried to the board of trade; they may also, with the sanction of the board of trade, compel local authorities (of which by the parliamentary report of 1861 there were about 170) to erect, change or discontinue lights or buoys. It will be seen that the above must be productive of much inconvenience, and, like all divided responsibility, must be injurious to its branch of the public service.

The first of these boards is one of the earliest corporations of England, existing as early as the reign of Henry VII, as an association for piloting ships. Its first charter was dated May 20, 1514, in the reign of Henry VIII, and with alterations under successive

sovereigns, was established as it is to-day by James I. The corporation is designated in its charter as "The Master, Wardens and Assistants of the Guild, Fraternity or Brotherhood of the most Glorious and Undivided Trinity, and of St. Clement in the Parish of Deptford Strond in the County of Kent." There are twenty-nine Elder Brethren, including two officers of the navy, and thirteen honorary members, who are elected as vacancies occur from members of the nobility; the remainder are retired officers of the merchant service. There is a body termed the Junior Brethren, who have no duties and whose number is not limited, who are elected by the elder brethren, and from whom the elder brethren are recruited as vacancies occur. Each active member of the elder brethren receives £350 a year from the revenues. The deputy master, the mastership which is a sinecure being held by one of the honorary members, is the executive officer, and is elected from the active list of the elder brethren.

It was not until 1565 that the corporation by act of parliament was empowered "to preserve ancient sea-marks, and to erect beacons, marks and signs of the sea." Under this act, Trinity house, in the reign of James I, claimed exclusive control over all lighthouses. The privy council in 1617 admitted their claim under the advice of Sir Francis Bacon, then attorney general; but a subsequent council, through pressure from the king, upheld by Bacon, who had changed his mind, gave the crown power to grant patents to other persons, and the king sold speculative permissions to do so, professedly whenever the Trinity board failed to meet the wants of mariners.*

That the Trinity house was somewhat slow to take advantage of the privileges granted in the charter of 1565 may be judged from the fact that no lighthouse was erected by the corporation until 1680. From thenceforward it received numerous patents for the erection of lights and collection of tolls in the same manner as such were granted to individuals. Copies of several such patents may be found in the reports of the parliamentary boards on British lighthouses of 1834 and 1845.

The board of commissioners for northern lighthouses was established in 1798 by act of parliament for the management of lights and buoys in Scotland; Trinity house having previously held in Scotland after the union, the same privileges as in England. The commissioners are unpaid and hold their positions *ex-officio*. "They consist of two law officers of the crown, the sheriffs of certain maritime counties, the

* British Almanac and Companion, 1873.

provosts of certain royal burghs, and the provost of Greenock." They are, in the words of an English writer on the subject, almost without exception merchants or lawyers. None of these gentlemen can be supposed, excepting in casual cases, to know anything of the subject; but the disadvantage arising from the constitution of the board has been counteracted in a great measure by the employment as their engineers of very able men; the Stephensons for three generations being the chief power in the corporation. The northern lighthouses thus were for many years far in advance of those of England and Ireland. They were the first to adopt improvements, and have given to the world some of its finest examples of lighthouse architecture and engineering. Taken altogether, the Scotch lighthouse board may be said to have shown remarkable excellence and efficiency, due, however, to the wisdom which subordinated the inexperience of the individual members to the skill and knowledge of the able men they employed as their executive officers, the Stephensons just mentioned.

The Ballast board of Dublin was incorporated in 1786, and in 1810 the control of the Irish lighthouses was given to it. There are about twenty members, few having any acquaintance with nautical or scientific matters; the lord mayor and high sheriff of Dublin are members *ex-officio*; three of the aldermen of Dublin are also members, and the remainder are members of the chamber of commerce, directors of railways, &c. The inspector of the lights under them is an officer of the royal navy.

It was not until 1836 that the entire control of the coast lighthouses of England and Wales was vested by law in the Trinity corporation; harbor and other local lights being still maintained by local corporations. Under the act of this date the interest of the ten coast lighthouses which still remained in private hands, was bought by the board for the great sum of £1,182,546. The Smalls, Spurn, and Skerries brought respectively £170,468, £309,531, and £454,984, the net revenue of the last named having been in 1840 £20,042. When it is understood that sometimes as much as twenty per cent. was allowed for the collection of these revenues, it will be seen what an enormous and unjust tax this was upon commerce. Prior to 1836 the tax was from one-sixth of a penny to a penny a ton upon all ships at each time of passing a light; but later, a uniform rate of half a penny a ton, with some few exceptions, was established; national vessels, fishing vessels, and vessels in ballast being exempt.

These dues are collected by the officers of customs, and constitute a lien upon the vessel or her equipment; they are now paid into "the

mercantile marine fund," which is recruited by fees received by the board of trade under the merchant shipping act, arising from granting of certificates, registration, &c.; by light-dues received by the Trinity house, the commissioners of northern lighthouses, or the port of Dublin corporation; by all money received by the Trinity house for lastage and ballastage in the river Thames, and by all money accruing to government in cases relating to wrecks or salvage.

"Each of the general lighthouse authorities has the power," in the words of the act, "with the consent of her Majesty in council, to do any of the following things:

"To exempt any ships or any classes of ships, from the payment of light-dues receivable by such authority.

"To alter the times, places and modes at and in which the light-dues receivable by such authority are payable.

"To substitute any other dues or class of dues, whether by way of annual payment or otherwise . . . for the dues payable to such authority for the time being."

"Tables of all light-dues and a copy of the regulations for the time being in force, shall be posted up at all the custom-houses in the United Kingdom."

It will thus be seen that the dues may vary from year to year, but a general idea of the expense to shipping may be gathered from the fact that the line of American steamers from Philadelphia to Liverpool pays about $250 per voyage to the English and Irish lights. A vessel of 1431 tons from New York to Liverpool in 1877 paid £16 2s 3d; one of 533 tons from New York to Belfast, £8 18s 6d; one of 1316 tons from New York to London paid £28 8s 4d. In earlier days these dues were much greater; a case being cited on the floor of the house of representatives in 1804, of a ship of 284 tons from New York to London paying £34 light dues.

Several efforts have been made to bring about a juster policy on the part of the British government by our own, but the fact that direct taxation would be increased by the amount necessary to support the lighthouse system has been the real hindrance. The United States has uniformly protested against taxes of this kind imposed on shipping, and was the first to make an effort to abolish the Sound dues collected by Denmark, the proposition to pay the capital value of the annual collections being made on the basis that these were made for the support of aids to navigation, the United States refusing to recognize the right of Denmark to tax vessels simply for the use of these waters as a highway. Great Britain paid more than a million

sterling, or more than half the entire amount; the United States paid $393,011, and in a convention concluded in Washington, April 11, 1857, the entire freedom of the Sound and Belts was guaranteed to American vessels, and that no dues should be charged for lights or buoys maintained by Denmark.

Similar dues had been levied by Hanover on shipping using the Elbe. These were extinguished in 1862 by the payment on the part of the United States of $36,000; other commercial nations paying in proportion to their commerce on the river. In 1864 we agreed to pay, in ten annual payments, the sum of $550,000 as our share in the liberation of the navigation of the Scheldt from the tonnage dues previously charged.*

We thus see that England has not been alone in the enforcement of such a tax, though I doubt if all would ever be willing to assist in the capitalization of the British lighthouse dues, as in those just before noted. It would require an aggregate of over £10,000,000 sterling to yield an interest at four per cent. equal to the present annual dues. This should be done by Great Britain herself. Our own system of absolute freedom from direct charges of any kind upon shipping, the expense of maintenance of lights, &c., being borne by the public treasury, seems the only really enlightened and fair policy.

The total revenue of the British lights under the three public corporations, for the year ending March 31, 1878, was £408,521, divided as follows: Trinity house, £323,476; Irish board, £31,022; Northern, £54,022; about seventy per cent. of this sum was paid by British shipping. The expenditures for the same year were as follows:

	Trinity House.	Irish Board.	Northern Board.
Maintenance of lighthouses	£29,649	£30,477	£25,544
Maintenance of light-vessels	46,351	15,978	....
Maintenance of buoys and beacons	8,905	2,394	1,584
Maintenance of steam and sailing vessels	49,781	13,570	11,125
Salaries of the establishment	19,006	3,992	3,029
Office and house expenses	6,393	2,749	1,034
Miscellaneous expenses	3,066	2,519	2,091
Charges for collection	5,224	1,345	519
Superannuations of officers and clerks	8,541	2,086	2,802
Stores, labor and materials	34,160	....	....
New works	34,143	11,806	4,962
	245,224	86,917	52,695
Or a total of		£384,836	

* Penn Monthly, July, 1873.

This forms much the largest charge upon the mercantile marine fund, the total of whose dues in the same year was £534,667.

In later years the British lighthouse boards have been among the foremost in the advances made in lighthouse illumination, Faraday and Tyndall both having given their services to the Trinity corporation. Several electric lights are in operation on the English coast, and much attention has been given by the Irish board to gas as an illuminant, with great success; gas is used in many cases also in England and Scotland. The buoyage of the coasts of the United Kingdom has, however, offered a better opportunity for the display of originality and diversity than have the lights. The report of the parliamentary committee of 1861 says, "Until lately there has been no attempt at uniformity in any part of the British isles, but the northern commissioners adopted a system, the main feature of which is placing red buoys on the starboard hand on entering a harbor and black on the port hand. The Irish board have frequently adopted a system too, but it is exactly the reverse of the Scotch; and only last year the Trinity house decided to buoy channels uniformly, but on a totally different plan, namely, red and black buoys to starboard and checkered to port, but they do not contemplate applying it to channels already buoyed. . . . In the meantime some of the local authorities, as those at Liverpool and the Clyde, have adopted systems of their own, which may or may not be the same as that of the general authority in the same country."

The system adopted by Trinity house has been, I believe, generally extended, and is to place red or black can buoys on the starboard hand on entering, and buoys of the same color either checkered black and white, or red and white, or marked in vertical stripes of these colors, on the port hand. Turning points are marked by nun buoys, and middle grounds by buoys with horizontal stripes, black and white or red and white, according to the color in use in that channel; wrecks are distinguished by a green buoy. The spar buoy in such general use in this country is not used in the United Kingdom, though as a day mark it is as a rule more easily seen than the can or nun. The latter, however, are much more easily distinguishable at night.

The fog signals in use do not differ materially from our own, the Daboll trumpet and the siren both being largely used, excepting that guns are sometimes used, which are fired at fixed intervals, and a rocket fog signal has been adopted, which is discharged at fixed intervals and explodes at an elevation of about four hundred feet. There

is no doubt of the value of such signals as this last, as in addition to the noise of the explosion there is the general illumination of the fog or glare from the light, especially marked in cases of red colored flame. The intervals of the sounding of the English fog trumpets appear much longer than it has been thought advisable to make them in this country; that at Bardsey island being sounded but once in five minutes, and three is a frequent interval.

Some of the English light-vessels are fitted with revolving lights; the use of these being not uncommon also on the coasts of continental Europe in general. In other respects they are not unlike our own. Among the regulations governing them, which are not in use in this country, are to be noted that a white light is exhibited from the fore-stay of the vessel for the purpose of showing in which direction she is riding.

When driven from position, a fixed red light is exhibited at each end of the vessel and a red flare shown every quarter of an hour.

When a vessel is seen standing into danger, a gun is to be fired until observed by the vessel; also the signal flags of the commercial code, signifying "you are standing into danger," are to be hoisted and kept flying until answered.

The use of colored sectors to distinguish shoals, etc., is much used in the English lights; the first order light of Usk, for instance, showing white from NE b E$\frac{3}{4}$E to NNE, red from NNE to N b W $\frac{1}{2}$W, white from thence to NNW$\frac{1}{2}$W, red from thence to the land. Between W b S$\frac{1}{2}$S and SW b W$\frac{1}{4}$W it shows green.

Their system regarding keepers is, however, much in advance of our own. The Trinity regulations require that applicants shall be between nineteen and twenty-eight years of age, of good character and physique, and having a common English education. There are always eight candidates under instruction at Blackwall and two at the South Foreland light, the latter learning the management of the electric light at that station. As vacancies occur they are filled from these men. Four classes of certificates are given: The first for competency in light-keeper's duties; the second for competency in the use of tools and the management of the steam engine; the third includes instruction in the management and care of the electric light, and the fourth the management of fog signals. When no longer able to do service, keepers are pensioned. Of course an elaborate system, such as the above, cannot be hoped for here until permanency of position is assured the keeper during good behavior.

Other Lighthouse Establishments.

The lights of France, previous to 1792, belonged, with few exceptions, to local corporations; in that year their charge was assigned to the ministry of marine, but the execution of the works was in the hands of the ministry of the interior. In 1806 they were placed under the administration of roads and bridges, and in 1811 the lighthouse commission was organized, "composed in the beginning of three naval officers, three members of the Institute, and three inspectors-general of roads and bridges." The following actual membership gives an idea of its present composition: the minister of public works, who is *ex-officio* president; a retired rear-admiral, member of the bureau of longitude; a rear-admiral on the active list; a captain in the navy; an inspector-general of roads and bridges and naval works; an inspector-general of marine engineering; a retired inspector-general of roads and bridges; the hydrographer-in-chief to the admiralty; a civil member of the bureau of longitude; a member of the academy of sciences, and finally another inspector-general of roads and bridges, director of the service of lights and buoys, who was secretary to the commission.

There is of course at the present time no differences between the French system of lights and those of our own or Great Britain. The entire organization seems to be one of high efficiency, and takes rank among the first as to beauty and excellence of buildings, completeness of apparatus, and character of *personnel.* The keepers, as those of England, hold permanent positions and are uniformed.

The buoyage differs but little from our own: all the buoys left on the starboard hand coming in from sea are colored red, with a white band immediately below the top. Those on the port hand are black; those which may be left on either hand are painted in red and black horizontal bands. The colors may be uniform over the buoy, or divided up to form various designs on a white ground, such as checkers, horizontal bands or vertical stripes, in case of unusual necessity for distinction. Upon each buoy is painted the name of the place marked, and each, excepting those horizontally striped, has its number, the system of numbering being the same as our own.

The administration of the lighthouse system of Spain is similar to that of France. In Holland the management is under the minister of marine.

In Belgium, the construction is under the minister of public works, but the lighthouses when completed are handed over to the direction of the navy, and the expenses are estimated in the naval budget. The buoy system of these last two countries is the same; white buoys being left on the starboard hand in entering from sea, and black on the port; red buoys are placed at the separation of two channels.

The lighthouse establishments of Austria, Denmark, and Russia, and the German Empire, are all under the ministry of marine. Each nationality has its separate system of buoyage. It is much to be regretted that there could not be devised an international system of buoyage common to the world, which would obviate the many chances of mistakes and misunderstandings which must now occur.

The following table gives the coast and harbor lights of the world in 1879:

British America	416	Portugal	19
United States	708	Italy and adjacent islands	219
West Indies	121	Malta	6
South America	83	Austria	107
Pacific Islands	10	Turkey	88
China	33	Greece	51
Japan	52	Russia	129
Australia	110	North Germany	113
Tasmania, New Caledonia, and New Zealand	46	Denmark, Norway and Sweden	318
Siam	1	Egypt	11
Cochin China	3	Syria	19
England, Scotland and Ireland	633	North Africa	53
Belgium	24	West and south coast of Africa	53
Holland	143	South and east coast of Africa and islands	26
France	353	India	165
Spain, Canary Isl. and Morocco	203		
Total			4416

This great number speaks well for the world's humanity, and is a wonderful advance over the meager showing of eighty, or even fifty years since; an advance, too, more marked in quality even than in numbers.

NOTE.—The following were used in the preparation of this paper, viz: Documents relating to lighthouses; Laws relating to lighthouses, 1789–1855; Annual reports of the U. S. lighthouse board; Illumination and Beaconage of the Coasts of France, (Reynaud, inspector general of bridges and roads, and director of the

light and buoy service, translated and published under the direction of the lighthouse board); Reports of the British parliamentary commissioners on lighthouses of 1834 and 1846; Extracts from British lighthouse reports (which embody the report of the commission of 1861); The merchant-shipping acts of Great Britain; Stephenson on lighthouse illumination, &c.; Appleton's American Cyclopedia and Encyclopedia Britannica, (articles, lighthouses); Lighthouse establishment of the United States, by A. B. Johnson, chief clerk of the lighthouse board, republished from Appleton's Annual Cyclopedia, 1880; and Lighthouse lists of the world.

NAVAL INSTITUTE, ANNAPOLIS, MD.

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REAR-ADMIRAL C. R. P. RODGERS, U. S. N., in the Chair.

THE NAVAL CAMPAIGN OF 1812.

BY PROF. J. RUSSELL SOLEY, U. S. N.

In order to understand fully the merits of the early actions of the war of 1812, it is necessary to notice for a moment the policy of the naval administration during the period preceding the war, and the condition of the navy when the war broke out. The navy of that day and of the present really dates from 1794, when an act of Congress provided for the building of six frigates, to check the depredations of Algerine corsairs.*

The old revolutionary navy had entirely passed out of existence; and though some of the senior officers of the new ships were selected from among the well-known revolutionary names, they were men who had been for ten years in private life, and their juniors had never before seen any naval service. Selected hastily, most of them in the course of a few months, the corps of officers was necessarily an ill-trained and unwieldy body; and Morris tells us in his autobiography how imperfect the selection was. Algiers gave the new navy nothing to do; but, fortunately for the service, the energetic action of the Congress of 1798, in declaring reprisals upon French armed vessels, gave it active and salutary occupation. By the autumn of 1798 nearly the whole fleet, composed of all the frigates that were ready, and many other vessels, numbering altogether about twenty, were cruising in the West Indies,

*Act approved March 27, 1794.

where they remained for two years. In 1801, the Peace Establishment Act, by reducing the number of officers in all grades, while it operated severely upon some of the veterans, nevertheless proved of substantial benefit in winnowing the service of most of the chaff that had entered in 1798. The officers who remained, and who formed the nucleus of the modern navy, comprised a large number of able men, most of them young men, who were animated by an intense *esprit de corps*, and ambition for the profession, and who developed later an extraordinary aptitude for it. All that they needed was training in active service, and a field for the exercise of their undeveloped powers. This came to them in the Tripolitan war, which occupied the navy for four years. It gave the junior officers the best possible training, under such able commanders as Dale, Rodgers, and Preble; and the eagerness with which they seized every opportunity for winning fame for the service shows the zest with which they had entered upon the profession.

The foreign policy of the administration during the next few years was one of peace and self-abnegation. The wars of Napoleon were then at their height, and the United States suffered the humiliations of a timid neutral between two unscrupulous belligerents. This timidity arose not so much from the weakness of the state as from the weakness of parties. The naval campaign against France in 1798 had been very successful, as were subsequently the naval campaigns against England in 1812; and a bold policy might have led to a like success in 1805. But, unfortunately, the rivalry of France and England was reflected at home. The federalists would not hear of a war with England, nor the anti-federalists of hostilities with France; and though the former were generally the advocates of a spirited foreign policy, yet their indignation was never very marked upon a question of English aggression,—and John Quincy Adams tells us that he abandoned his party because it resented the outrage on the Chesapeake in so lukewarm a fashion.

By way of retaliation for belligerent encroachments, Jefferson adopted the self-denying measure of the embargo, which forbade the departure of any ships from the ports of the United States, except foreign ships in ballast and coasters. As an offensive measure it was a failure, while its effect at home was most disastrous. As it soon became evident that it threatened the mercantile interests of the country with ruin, it was replaced by a prohibition on importation from France and Great Britain. This was so far better, in that under

it American vessels were free to go abroad and pursue such trade as they could. But it had one fatal result, which must have been foreseen at its passage. Fully nineteen-twentieths of the revenue of the state was derived from customs, and by the non-importation acts more than half the usual amount was withdrawn. The revenue fell from $17,000,000 in 1808 to $7,770,000 in 1809; and the government, while it was pursuing an aggressive foreign policy that might end in war, was voluntarily cutting off its own resources. The act was repealed in 1810, but the government, to save its self-respect, was given authority, in case either power revoked its noxious decrees and the other refused, to revive the prohibition against the offender.

When Congress met, late in 1811, a strong war-party of younger men obtained the control of affairs. Though both nations had committed aggressions, and though France was far less capable of effective hostilities, the old antipathy of the anti-federalist party for Great Britain directed the energies of the new movement chiefly against that power. For this there was some excuse, in that France had latterly made a show of concession, to which England, more candid and direct in her negotiations, had failed to respond. The relations with England were, moreover, complicated by the grievance of impressment. The dominant party carried everything before it, and on the 18th of June, 1812, war was declared against Great Britain.

During all this period, when a rupture often seemed imminent, little was done to improve the navy. The last vessels of any size that were added to it were the brig Hornet in 1805 (later altered to a sloop), and the sloop-of-war Wasp in 1806, rating 18 guns each. The remaining efforts of the naval administration were devoted to the building of gunboats.

Attention was first directed to this species of war-vessel by their success in the operations before Tripoli. For special services, such as that for which Preble employed them, as auxiliary to larger vessels, in flotilla-engagements in shoal waters, and for attacking the picaroons and other piratical craft that infested the West Indies, they were no doubt of some use. But Jefferson's idea—and it was peculiarly his idea—was to transform the navy into a fleet of gunboats, to do away with the frigates, and if the country became involved in war, to make it a defensive war solely. It was claimed for the gunboats that, together with fortifications, they would be the best protection for coasts and harbors, the mouths of rivers, and shoal waters in general. This scheme of defence was a part of the isolating policy of the gov-

ernment,—a policy which sought to draw the nation in upon itself, to surround it with barriers, to destroy intercourse and commerce with the rest of the world, and to repel attack by means of forts, embargoes, and prohibitions on importation.

During Jefferson's administration, Congress was ready to carry out the plan to its fullest extent. In 1806 and 1807 over a million of dollars were expended in the building of gunboats. The materials for six ships-of-the-line, which had been accumulated during Adams's administration, were devoted to the same object. One hundred and seventy-six gunboats were built, and distributed in the bays and harbors; and the ablest of the older lieutenants were placed in command of flotillas, to enforce the embargo at the different ports, and to suppress the commerce they were commissioned to protect.

In 1809, upon a change of Presidents, Congress made an examination of the working of the system, and it was found that the one hundred and seventy-six gunboats in the service had cost $1,800,000. The cost of the frigate President, mounting 56 guns, armament and all, was $220,000. Hence the money that was wasted on the gunboats would have built eight first-class frigates; frigates which the British authorities always asserted were equal to small line-of-battle-ships. It was also found that the annual cost of a frigate carrying 56 guns was $120,000, while that of fifty-six gunboats carrying one gun each was $650,000.

These figures put an end to the gunboat system. No more were built, and during the next three years they consumed the revenue without giving any proof of usefulness. In March, 1812, an act was passed directing that they should all be put out of commission. During the war the government got rid of them as rapidly as it could; and finally only three remained in the service, the rest having been sold for about one-tenth of their original cost.*

During this period the navy proper, apart from the gunboats, maintained a precarious existence. The government did not look upon it with favor, and its administration was none of the best. In 1806 Congress fixed the number of seamen to be employed at nine hundred and twenty-five; not enough to man three frigates.† The affair of the Chesapeake in 1807 was used as an argument for the abolition of the navy, on the ground that foreign nations would not inflict insults upon

*For a full account of the legislation in regard to gunboats, see Goldsborough's Nav. Chron., p. 322.

†Act approved April 21, 1806, § 3.

our ships-of-war if we had no ships-of-war to be insulted. Though foreign relations grew more and more complicated, the same arguments, or unreasoning denunciations, were repeated year by year in the debates on the appropriation bill. In 1808, in a debate upon increasing the force in commission, a representative from South Carolina said that "he was at a loss to find terms sufficiently expressive of his abhorrence of a navy. He would go a great deal further to see it burned than to extinguish the fire. It was a curse to the country, and never had been anything else. He had always voted against these high federal measures, and he thanked God he now had an opportunity to vote against them again." *

Strange as it may seem, these words represented the general opinion of the majority in Congress. The "abhorrence" was a matter of party discipline and party education. So strong was the hostility to the navy, that it is almost a wonder that the service was not abolished. But it found some defenders, men who, though in the minority, were not to be silenced by the partisans and intriguers who at that time controlled the legislature. It is a fact to be remembered by the navy, that in this period, when it was threatened with annihilation, it was ably and courageously supported by three statesmen from Massachusetts, in the Senate by James Lloyd, and in the House by Josiah Quincy and Joseph Story. Partly through their efforts, an act was passed early in 1809, directing the fitting out of the President, United States, Essex, and John Adams; and authorizing the preparation of the other ships, the appointment of three hundred midshipmen, and the employment of three thousand six hundred additional men. In the debate upon the bill, Quincy said: "I have been a close observer of what has been said and done by a majority of this House, and for one I am satisfied that no insult, however gross, could force this majority into a declaration of war. To use a strong but common expression, they could not be kicked into a war. What has this majority actually done during the two years in which the people have been kept in daily anticipation of war, toward the maintenance of our rights? We have built one hundred and seventy gunboats, and we have a hundred thousand militia in requisition. Do we mean to fight Great Britain with these? Are they competent to maintain our maritime rights?"† In the same

* Hon. D. R. Williams. The debate took place April 23, 1808. Ann. of Cong., 10th Cong., 1st sess., vol. 2, p. 2270.

†Ann. of Cong., 10th Cong., 2d sess., H. of R., Jan. 19, 1809.

debate an increase of the navy was recommended by Story, by the construction of fifty fast frigates. In reply to the objection that they would all be captured, he said: "I was born among the hardy sons of the ocean, and I cannot so doubt their courage or their skill. If Great Britain ever obtains possession of our present little navy, it will be at the expense of the best blood of the country, and after a struggle that will call for more of her strength than she has ever found necessary for a European enemy."* These predictions were amply fulfilled.

The act which followed this debate, and one passed in March of the same year (1809) to augment the marine corps,† were the last measures taken for the increase of the navy before the outbreak of the war. For three years, with the prospect of war staring it in the face, Congress did nothing in the way of preparation, not even during the long session of 1812, when the leaders were resolved to bring about hostilities. This was not from apathy or want of interest, but from an active spirit of opposition to what the party had been taught to look upon as a "high federal measure." In this very last year, though the naval committee recommended ten new frigates, Congress only appropriated enough money to fit out the Chesapeake, Constellation, and Adams; and as if a war with Great Britain meant a desultory conflict for half a century, it provided for an expenditure of $200,000 annually, for three years, towards rebuilding three or four of the small frigates, too rotten to be repaired.‡ With such encouragement the navy went into the war.

At the outbreak of the war the United States navy, exclusive of gunboats, was composed of twenty-one vessels, of which fourteen were in commission. Of the other seven, one was on Lake Ontario, three were repairing, and three were beyond repair. Of the fourteen in commission, there were three frigates of 44 guns, one of 38, one

*Ann. of Cong., 10th Cong., 2d sess., H. of R., Jan. 4, 1809, p. 977.

†Approved March 3, 1809.

‡Act approved March 30, 1812. The third section of this act, which provides for rebuilding, designates the Philadelphia, General Greene, New York, and Boston, as the four to be rebuilt. Exactly why the Philadelphia should have been specified as one of the ships to be rebuilt is not apparent, that vessel having been burnt by Decatur in 1804, in the harbor of Tripoli. The act might as well have named the Bon Homme Richard or the Alliance.

of 32, and one of 28; while the rest were sloops, brigs and schooners, carrying from 10 to 18 guns each.*

On the other hand there were in the British navy at the beginning of the year 1812, two hundred and thirty-six ships-of-the-line, of from 60 to 120 guns each, and six hundred and fifty-nine vessels of the class of frigates and smaller. These figures represent all the ships in the navy; of those actually in commission for sea-service there were one hundred and two ships-of-the-line, and four hundred and eighty-two frigates and smaller cruisers.†

The enormous disparity between our own navy and that of the enemy struck the government so forcibly at the outbreak of the war, that it was decided at Washington to lay up all the ships in commission. This was the logical extension of the administration policy. It was a self-denying measure of the same character as the embargo. It was founded upon the assumption that, as the enemy's force was overwhelming, it would be futile for us to keep up any force at all. The war-policy of the government seemed to be to make a declaration, and to scare the enemy with bluster, if possible, but to avoid any formidable preparations, which would lead their adversary to a vigorous pursuit of the war. Our safeguard and shelter from the resentment of foreign powers was to lie in their contempt,—a feeling which it was our interest studiously to cultivate. In applying this policy to the navy the Cabinet was overruled by the President, who had only been persuaded to change his mind by the earnest remonstrances of Bainbridge and Stewart.

Under these circumstances little or nothing was expected from the navy, and so it was that when, in the first eight months, three British frigates and three brigs or sloops-of-war were captured in engagements with single ships, the country was taken by surprise, and

* The list of vessels in full is as follows: President, 44, Rodgers, at New York; Constitution, 44, Hull, at Annapolis; United States, 44, Decatur, at New York; Chesapeake, 38, Constellation, 38, repairing under act of March 30, 1812; Congress, 38, Smith, at New York; New York, 38, to be rebuilt; Essex, 32, Porter, at New York; Adams, 28, repairing under the act of March 30; Boston, 28, to be rebuilt; General Greene, 28, to be rebuilt; John Adams, 28, cruising off the coast; Wasp, 18, Jones, returning from Europe; Hornet, 18, Lawrence, at New York; Argus, 16, Sinclair, at New York; Siren, 16, Nautilus, 12, Vixen, 12, Enterprise, 14, Viper, 10, cruising at various points off the coast; Oneida, 14, on Lake Ontario.

†Abstract (No. 20) of ships in the Royal Navy. James, Naval History of Great Britain, vol. 6, appendix.

was ready to believe in the invincibility of American men-of-war. Accounts were distorted and exaggerated until the notion became general—a notion which prevails more or less in the popular mind to this day—that the victories of American ships during the war were won over superior force, and through the display of extraordinary prowess. As a matter of fact, however, in nearly every engagement in which we were successful, we had a decided material advantage at the start, in the number and size of the guns, in the composition and size of the crews, and in the strength and general equipment of the ships. Moreover, the crews of American ships were in many cases superior in their discipline to the English, and, above all, their skill in gunnery was far in advance of their opponents. Many of these advantages must be set down to the credit of the officers, no less than the successful handling of the ships in action. The superiority in equipment was also largely due to the energetic and wisely-directed pressure of officers upon the naval administration. English officers, on the other hand, from long-continued success had grown slack, and the twenty years' war in Europe had exhausted the supply of good seamen, so that some of their ships on our coast were undermanned, or supplied with raw crews, pressed into the service. It was therefore doubtless due to the efforts of our officers that the advantages were on our side; still, there is no denying that in most of the single engagements we had the advantage.

As our officers had been careful and judicious in preparation, so they fought their actions with courage and skill; and our naval historians only injure their cause by seeking to represent them as victories won in the face of heavy odds. As far as bringing on an engagement was concerned, the American officers were generally less ready to do so than their opponents; and rightly, for the loss of a single ship would have been a far greater calamity to the country than the loss of a dozen would have been to Great Britain. England might readily have sacrificed twenty frigates in bringing all our ships into action, and not have felt the loss seriously; while the series of actions would have extinguished our navy altogether. Thoughout the whole war, American commanders followed a far more cautious system of tactics than the English, and on several occasions chose to avoid a combat with a ship nearly equal, rather than risk the safety of one of our diminutive fleet. The event proved their wisdom: of the seventeen sea-going vessels that could be utilized at the beginning, ten were burnt or captured during the war. The seven that

escaped, comprising the Constitution, United States, Congress, Constellation, John Adams, Hornet, and Enterprise, were only saved by the exercise of the greatest care and prudence.

The English mode of fighting, on the other hand, which they had learned in their wars with the French, was to attack any enemy they met, even though the odds were very much against them, and either demoralize him by a tremendous fire at close quarters or carry him by boarding. Their great superiority in discipline and training, and their wonderful solidity and tenacity, generally gave them the victory. Their uniform experience had taught them to think little of manœuvering for advantages in sea-fights, and to set a far higher value upon sheer bravery and *élan* in making an attack. The Revolution of 1789, by introducing ideas of equality totally incompatible with discipline at sea, had disorganized the French navy; and, while in this condition, it received those crushing defeats from which it never recovered. In fighting with one of their ships, an enemy gained no special advantage by manœuvering; in fact, he needed none. The boldest plan was the safest; to go directly up to his antagonist, batter him for a while, and then board, if he had not already struck. Hence the tactical skill, the art of manœuvering, the quality which in land operations is called strategy or generalship, where it is the leading qualification for a great military commander, was regarded as a thing of little moment by officers of the school of St. Vincent and Nelson.

During the war of 1812, and especially at first, the English captains used the methods that had previously proved so successful; and having everything to gain by victory, and little to lose by defeat, they could afford to run greater risks than the Americans. They had learned to look upon an engagement with a larger ship as attended with little danger; and they were surprised in turn to find that the dashing tactics of European warfare were at fault. Their enemy was wary, and manœuvred at a distance, using his long guns to advantage; his gunnery was most accurate, and told at long or short range with far greater effect than their own; his tops were filled with riflemen, expert marksmen, who brought down a man at every shot. This explains the readiness with which the Guerrière, the Java, and the Macedonian engaged a superior force, and it explains also the rapidity and certainty of the fatal result. We cannot have too much admiration for these fine displays of courage on the part of the English captains; and we need not on that account think that the wary and cautious tactics of our own officers showed a want of bravery, for Congress

by its scanty provision for the national defence had forced this policy upon them. In discussing these actions, Sir Howard Douglas, a writer of great reputation in his day, commends this quality of the American officers to the English navy, in the strongest terms, under the name of *circumspection.* But Sir H. Douglas wrote after the American war; the word circumspection, applied in the same way in 1810, would have been regarded by Englishmen as a euphemism for cowardice. Now, it is a noteworthy fact that all our captains in the frigate actions of 1812, Bainbridge, Hull, and Decatur, whose personal courage nobody can deny, had used this circumspection when engaged with an inferior force; while Lawrence, in the engagement with the Shannon in the following summer, though he had far greater need of it, in that he was more nearly matched with his opponent, went into the action with impetuous bravery, scorned all tactical advantages, and, after a gallant and bloody struggle, lost his vessel.

Before going into the details of the war, one word about the various accounts of it. Soon after its close several books were published in the United States, filled with the brag and bluster for which Americans have sometimes been, justly or unjustly, condemned. The English official reports were not for some time made public, and some of these books having found their way to England, aroused the indignation of naval officers who knew the facts as they were. Hence the English naval historians have made it a special duty to answer these pretensions, and we may be said to have brought on ourselves much righteous reproach. The principal history of the British navy during the wars of Napoleon,—from 1793 to 1815,—is written by a lawyer named James, and is a wonder of careful and minute research. In the volume on the American war, however, he has lost or sunk all sense of fairness or candor, and his bitter hostility to Americans, and especially to American naval officers, has made him rather the advocate of a cause than the annalist of a contest. He has devoted himself in this volume, with all the ingenuity and skill of a special pleader, to proving that the officers of the American navy, one and all, with the exception perhaps of Lawrence, who was beaten, were cowards, liars, and blackguards. No charges can be too severe, no language too abusive to describe their conduct. According to James, they never fought when they could run away, they paid no regard to truth in their statements, they treated their prisoners with brutality, they resorted to the basest fraud and trickery to deceive an opponent. I know of no book in the language which contains such a mass of

malevolent misrepresentations of acts and of motives, such petty slurs upon men's characters, such dirty innuendos, and such coarse and vulgar abuse. Of course the book is a gross libel; but it is, nevertheless, the highest authority in England on the subject of the great naval wars. It is hardly necessary to say that the fascinating pages of Cooper, with which we are all so familiar, cannot serve as an adequate answer to James. A single page of James shows more research than any chapter of Cooper; and it has always seemed to me a pity that no American officer has been found to write a complete refutation of the slanders of the English historian.

On the 21st of June, three days after the declaration of war, a squadron sailed from New York under the command of Commodore Rodgers, composed of the President, as flagship; the United States, Commodore Decatur; the Congress, Capt. Smith; the Hornet, Capt. Lawrence; and the Argus, Capt. Arthur Sinclair. The object of the cruise was the capture of a fleet of one hundred merchantmen, known to have sailed from Jamaica some time earlier for England, with a convoy. When two days out, on the morning of the 23d, the squadron fell in with and chased the British frigate Belvidera, Capt. Byron, armed, according to James, with 42 guns. When the chase began the Belvidera was about six miles off; but, in the course of the afternoon, the President, which was the fastest ship of the squadron, came up within half a mile of her, and perhaps nearer, and opened fire from her bow guns, doing some damage. Presently one of these guns, a 24-pounder, burst, and killed and wounded several officers and men. Among the wounded was Commodore Rodgers. The Belvidera returned the fire with four guns which had been shifted to her stern ports. A running fight was kept up in this way for some time, and as the ships in chase were gaining on him, Capt. Byron cut away some of his anchors, threw overboard his boats, and otherwise lightened his ship. This had the desired effect, and the President gradually lost ground. At midnight the chase was given up as hopeless. The loss on each side was a little over twenty in killed and wounded; most of the casualties in the President resulting from the bursting of the gun. Unfortunately, the delay prevented the squadron from overtaking the Jamaica fleet; and, after following it across the ocean, the ships returned late in August to Boston, having taken seven prizes.*

* Commodore Rodgers's report, Nav. Mon., p. 205.

At the time that the squadron left New York, the Essex was lying there, undergoing repairs. She was under the command of Porter, about this time promoted to a captain. On the 3d of July, her repairs being completed, she sailed on a cruise alone. On the 11th, at night, Porter came up with several vessels, which he learned were British transports under convoy of the frigate Minerva. Porter's intention was to run alongside the frigate and surprise her; but finding himself unable to do this, he cut off the nearest transport. The Minerva discovered the capture, but went on her way without molesting the Essex. The prize was ransomed for $14,000. She had on board between one and two hundred soldiers, on their way to Quebec to take part in the war.*

About a month later, on the 13th of August, the Essex fell in with the British sloop-of-war Alert, which engaged her, apparently without perceiving the difference in force. The action lasted only eight minutes. After a few broadsides the Alert surrendered, the men deserting their guns in a panic. The sloop had seven feet of water in her hold, and three men wounded. The Essex had no injuries or casualties. This was the first capture of a public ship of the enemy made by us during the war. It was chiefly remarkable for the disproportionate injury to the two ships and for the short duration of the encounter. The Essex was far superior in the number and weight of the guns, in the number of men, and in the fighting qualities of the ship; while the Alert, according to the English account, was, except in the commander, badly officered and manned, and the result showed unfavorably for the discipline and gunnery of her crew.

The prize was fitted as a cartel and sent with the prisoners to Newfoundland. Porter returned to the Delaware in September. During the cruise he made nine captures, and recaptured five American privateers and merchantmen, fourteen prizes in all. Two of these were burnt, one was recaptured by the Belvidera, and the rest were sent in or ransomed.†

Before this time, an English squadron, composed of the Africa, a 64-gun ship, and the frigates Shannon, Guerrière, Belvidera, and Æolus, under Commodore Broke of the Shannon, had assembled on the coast, and was watching for our cruisers. About the middle of

* Niles' Reg., 2, 366; Porter's life of Commodore Porter, p. 93.

† Porter's reports, Nav. Mon., p. 211; Admiral Porter's life of Commo. Porter, p. 94.

July the Nautilus left New York, and, a few hours after sailing, fell in with this squadron. All the usual measures were taken to lighten the ship and to aid her escape, but after a six hours' chase she surrendered to the Shannon.

On the 12th of July, four days before the capture of the Nautilus, the Constitution, under Captain Hull, left the Chesapeake for New York. On the afternoon of the 16th, she fell in with Commodore Broke's squadron, off Barnegat. I will not here go into the details of the famous chase, with which every one is familiar, and which we can now read in the spirited narrative of one of the principal actors, the gallant first lieutenant of the Constitution.* On the 19th, after three days of incessant toil and anxiety, the ship finally lost sight of her pursuers, and a week later she arrived safely in Boston.

After a week in port, Hull sailed on a cruise to the eastward. He took and burnt some prizes in the gulf of St. Lawrence; and hearing that the squadron from which he had recently escaped was in the neighborhood, he steered to the southward.

On the 19th of August, at two o'clock in the afternoon, when at sea, in about the latitude of New York, the Constitution made a strange sail to the southward and eastward. Hull had already had information that an English frigate was cruising alone, to the southward of him, and he suspected that this was the object of his search, and accordingly bore down for her. The wind was NW, and the strange ship was sailing close-hauled on the starboard tack. At three o'clock the two ships were near enough to make each other out, and Hull's conjecture proved to be right. The stranger was the frigate Guerrière, of 38 guns, according to her nominal rating, which had left the squadron of Commodore Broke, and was on her way to Halifax.†

* The Autobiography of Commodore Charles Morris, U. S. N. Proc. U. S. Naval Institute, vol. vi. p. 159.

† Four distinct accounts of the action between the Constitution and the Guerrière have been written by eye-witnesses. They are the official reports of Captain Hull (Naval Monument, p. 9), and of Captain Dacres (Gold's Naval Chronicle, vol. 28, p. 347); the narrative of "an officer of the Constitution," (Nav. Mon., p. 12); and Morris's narrative (Autobiography, p. 163). The description of the engagement in the present article is based on a collation of the four accounts. Each of the accounts contains particulars omitted by all the others; but they agree in all essential points, except in regard to the duration of the action, which Captain Dacres makes about an hour longer than the other authorities. Upon this point it has appeared to me that the weight of authority rests with the Americans.

At four o'clock the Constitution altered her course to SSW, gaining rapidly on her opponent; and at 4.45, being then between two and three miles distant, the Guerrière backed her main-topsail and waited for the American ship to come up. Upon this the Constitution took in her topgallant-sails, staysails and flying jib, took a second reef in the topsails, hauled the courses up, sent down the royal yards, prepared for action, and beat to quarters. At the same time she bore up and steered for the Guerrière's quarter.

The two ships now closed. At 5 the Guerrière hoisted her colors, and five minutes later she began firing. According to the American reports, all her shot fell short. They were, however, returned with a few shots from the bow guns, and soon after the Guerrière wore, to prevent raking. The Constitution changed her course a little, to clear her opponent's quarter, and at 5.20 the latter fired a second broadside, and wore ship again. This manœuvre was repeated three or four times, the ship discharging alternate broadsides as they were brought to bear. Finding that these movements separated the ships, Hull set his main-topgallant-sail and steered directly for the enemy, who, finding at the same time that his manœuvres gave him no advantage, gradually bore up, and ran off under topsails and jib, with the wind on the quarter. The two ships were now heading nearly east, the Guerrière being still ahead and to leeward; but the Constitution closed rapidly up on her port quarter,* at 5.45, and passed to her beam, at a distance of two hundred yards, and approaching nearer. At 6.05 both ships opened fire, as their guns could be brought to bear.

At this point the action may fairly be said to have begun, as little or no injury had been inflicted on either side up to this time. In a few moments, the heavy fire from the guns of the Constitution, double-shotted with round and grape, began to tell, and at 6.15 Hull had the satisfaction of seeing his enemy's mizzenmast fall. The natural effect of the loss of after-sails would have been to cause the Guerrière to fall off before the wind, and this would have defeated Hull's purpose of passing alongside of her to windward and giving her a raking fire as he crossed her bow. In fact, this intention on the part of the American captain was so evident that the Guerrière's helm was put hard a-port to keep her head off. But, curiously enough, notwith-

*Captain Dacres, in his official report, says that the Constitution closed on his *starboard* beam; but this is evidently a mistake, as all the other statements show, and as James points out distinctly in his account.

standing the loss of after-sails, and notwithstanding the port helm, the Guerrière came up in the wind, swinging round into just the position most favorable for the execution of Hull's judicious plan. This was no doubt due to the fact that the wreck of the mast falling over the side acted as a drag.*

The Guerrière's velocity being now retarded, Hull gradually ranged ahead, and at 6.20 he put his helm hard a-port to cross her bow and rake her. The loss of braces on board the Constitution and the disabling of her spanker and mizzen-topsail prevented her from coming to starboard as quickly as was desired, but she had time to give two raking broadsides, which swept the enemy's deck, and which were only answered by a few of his bow guns. The Guerrière's jib-boom had just crossed the Constitution's quarter-deck when the latter bore up, putting her helm a-starboard, to avoid presenting her stern to the enemy's broadside. This manœuvre resulted in the entanglement of the enemy's bowsprit and jib-boom in the Constitution's mizzen-rigging, and the Englishmen prepared to board. Morris, the first lieutenant of the Constitution, seeing this, suggested to the captain to call away the men to repel boarders. This was accordingly done, but at the same moment Morris, who was standing on the taffrail and attempting to pass some turns of the main-brace over the Guerrière's bowsprit, to keep her fast, was shot through the body, and the two ships separated. During the period of close contact, the wads from the enemy's bow guns had

* The statements in regard to the fall of the mizzenmast rest on the authority of Captain Dacres, who says in his report (Naval Chronicle, vol. 28, p. 347): "Our mizzenmast went over the starboard quarter and brought the ship up in the wind." The statement is borne out by the narrative of the "officer of the Constitution," Nav. Mon., p. 13. It is not quite clear how the fall of the mast over the *starboard* quarter could have the effect of throwing the ship's head to port. Captain Brenton (Naval History of Great Britain, vol. 2, p. 453) gets over the difficulty by simply saying that it fell over the larboard side, notwithstanding Captain Dacres's statement to the contrary. Of course, if this was the case, the wreck of the mast acted purely as a rudder. James (Nav. Hist., 6, 99), having already changed starboard to port, where it occurs earlier in the report, seems to have felt a delicacy about taking further liberties with the statements of Captain Dacres, and leaves it on the starboard side, saying that "by dragging in the water it brought the ship up in the wind." If this statement is correct, it must have been due to the fact that the mass of the wreck falling some distance off, had a motion of its own, independently of the motion of the ship with which it was still connected by part of the shrouds or rigging, and, acting as a huge drag, it threw the ship's head around, in the same way that a steamer's stern line, made fast to a wharf, will throw her head off in the opposite direction.

set fire to the cabin of the Constitution, but the fire was quickly extinguished. A few moments later the Guerrière's fore and main-masts went by the board, and at 6.30 she fired a gun to leeward in token of surrender.*

The fate of the battle being now decided, Hull leisurely set his fore-sail and main-sail, and hauled to the eastward to repair damages. All the braces were shot away, the standing and running rigging was somewhat cut up, and some spars were lost. After passing half an hour in reeving new braces and in repairing the other injuries, he wore round and took a raking position to leeward of the enemy, within pistol-shot. Dacres meanwhile had been making a gallant effort to get his ship under command to renew the action, but after clearing away the wreck, his spritsail-yard, his only remaining reliance, was carried away, and the Guerrière lay a helpless wreck, in the trough of the sea, rolling her main-deck guns under water. When the Constitution returned to her at 7 o'clock, she surrendered.

Finding it impossible to take the Guerrière into port, on account of her shattered condition, Captain Hull set her on fire the next morning. She had then four feet of water, and was sinking fast. In the fight she had fifteen officers and men killed, and sixty-three wounded, six of them mortally. The Constitution received some injuries in her masts and rigging, though nothing that was not easily repaired. Her killed and wounded together amounted to fourteen.† The defeat was as overwhelming as it was unexpected. In half an hour's close action an English frigate had been compelled to surrender, dismasted, sinking, a complete wreck, with one-third of her force disabled.

To understand the merits of this engagement, and of those which followed, which created so much elation in America and so much depression in England, it is necessary to examine the construction and armament of the American and English frigates of the period. In the first place, we must drop out of our minds any consideration of the *rates* of men-of-war of this period, which were purely conventional, and bore a varying relation to the strength of the armament. The three largest frigates in our navy, the President, United States, and Constitution, were all nominally ships of forty-four guns, but

* Dacres says nothing in his report about having fired a gun to leeward, neither does Hull; but it is expressly mentioned by Morris, and by the "officer of the Constitution," whose succinct account was very generally published soon after the engagement.

† According to Hull, seven killed and seven wounded; according to Dacres, who could hardly be presumed to know accurately, nine killed and thirteen wounded.

in point of fact they usually carried fifty-six. On the other hand, the British 36 or 38 gun frigates carried from forty-five to forty-nine guns. In the second place, the guns themselves in the American frigates were much heavier than those in the British. There were two classes of guns on board of all these vessels, long guns on the gun-deck and carronades on the spar-deck. Of the latter, it is only necessary to say here that they carried a heavier shot than the others, but had a much shorter range; hence they required a smaller charge, and were shorter and lighter, and could be worked by a smaller number of men. Several of these were placed on the spar-deck. In the English frigates this was not a continuous deck, but consisted only of the quarter-deck and forecastle, connected by narrow gangways, but open in the middle to the gun-deck. As a rule, the English gun-deck battery consisted of 18-pounders, and the guns on the forecastle and quarter-deck were 32-pounder carronades, while our 44's had 24-pounders on the gun-deck and 42-pounder carronades above. The Constitution was an exception, however, in that she had 32-pounder carronades on her spar-deck, like the English frigates, instead of 42's, as in the President and the United States. She had originally been armed like the others, but the strain was found to be too great, and the change had been made the year before. She retained her 24-pounders, however, in her gun-deck battery. The only true way to estimate the effective force of these ships is by comparing the weight of their shot at a single discharge. According to this method, the battery of the Constitution was more powerful than that of her opponent by one-half.

In regard to other material advantages, that is, advantages which were not due in any way to the qualities of the officers and men, the size of the Constitution, her sailing qualities, the thickness of her frame, and the stoutness of her masts and spars, were all greatly in her favor. Moreover, her crew numbered about two hundred more than that of the Guerrière, and they were more generally picked men.*

* The force of the two ships is given by Emmons (Statistical History of the U. S. Navy, p. 56,) as follows:

CONSTITUTION: 468 men.

No. of guns.	Weight of shot.
30 long 24-pounders	720 pounds.
24 32-pounder carronades	768 "
1 long 18-pounder	18 "
55	1506 "

Taking all these facts into consideration, they do not account for the vast difference in the amount of injury inflicted. What then were the other elements of our success? It cannot be laid to extraordinary feats of daring; the conspicuous display of bravery lay rather with the smaller ship, which was ready for a plucky encounter with a superior force. It was not wholly in the discipline of the crew, though this was of the highest importance, and though the Constitution was remarkable in this respect, as was shown by the fortitude with which her escape was conducted a few weeks before. The all-important point of difference, the one which served us most during the whole war, was the practical training and skill of our crews in gunnery. They had constant exercise in target-practice, and, as James says, "ten shot, with the necessary powder, were allowed to be expended in play, to make one hit in earnest."* The English crews, on the other hand, rarely or never fired their guns except in an engagement, and stricts limits were fixed to the consumption of ammunition in gun-practice. Hence, in all our actions, a short time sufficed to disable the enemy; he was hulled repeatedly, and his masts were shot

GUERRIÈRE: 280 men.

No. of guns.	Weight of shot.
30 long 18-pounders	540 pounds.
2 " 12-pounders	24 "
16 32-pounder carronades	512 "
1 12-pounder carronade	12 "
49	1088 "

Other authorities differ in some points from Emmons, but generally in unimportant points. James gives the Constitution 468 men and boys, and the Guerrière 244 men and 19 boys, and 6 Americans, who remained below (by Captain Dacres's order) during the action. In estimating comparative force, however, James always leaves the boys out of the account, because the English ships generally had a greater number than the American. Brenton (2, 455) gives the Constitution 476 men, following Dacres's report. Dacres gives the Constitution one additional 18-pounder, in which he is followed by James and Brenton, making a total of 56 guns. In regard to the Guerrière's armament, James puts two 9-pounders in place of Emmons's 12's, and makes the single launch-carronade an 18-pounder, instead of a 12-pounder as given by Emmons. This leaves the total number of guns and the weight of shot the same; though James, by a train of ingenious reasoning, which is thoroughly characteristic, endeavors to argue out of practical existence three of the guns of the English ship, thus reducing the number in his statement of "comparative force" to forty-six.

* Naval History of Great Britain, vol. 5, p. 373.

away, before he had accomplished more than a slight damage to our sails or our rigging.*

Another illustration of this is the action between the Wasp and the Frolic. The Wasp had left the Delaware on the 13th of October, and on the 18th met the brig Frolic, Captain Whinyates, at sea, about east of Albemarle Sound, in charge of a convoy from Honduras to England. As to armament, the two vessels were nearly matched. Each carried sixteen 32-pounder carronades, and from two to six additional guns, about the number and caliber of which accounts differ. The only long guns carried by the Wasp were two 12-pounders. She is also said to have carried two brass 4-pounders in her tops. The Frolic, according to a very explicit statement of Captain Jones, in his report of the action, carried, in addition to her carronades, four 12-pounders on the main deck, and two 12-pounder carronades on the top-gallant forecastle.† James denies that the Frolic carried six extra guns, and puts the number at four, two long sixes, and two 12-pounder carronades, one of which was lashed on the forecastle, and both of which he throws out of the calculation of comparative force.‡ No authority is given for these statements, and unless sustained by other testimony, they cannot be considered as of equal weight with those of Captain Jones, who had clearly the best opportunity of knowing. Captain Whinyates says nothing in his report about the force of either ship.§

In other respects, the advantages were on the side of the Americans. The officers and crew of the Wasp numbered one hundred and thirty-eight, while those of the Frolic, men and boys, only numbered

* The above was written before the discovery of the Morris autobiography. How far the views of the writer are borne out by the high authority of Commodore Morris may be seen from the following passage, relating to the causes of American success in 1812. "The remote cause, as it appeared to me, was to be found in the confidence of our enemy, and in distrust of ourselves to contend successfully against them; in the neglect of careful exercise, which resulted from the enemy's confidence, resting on former success; and, on our part, in the unwearied attention of our officers to devise and bring into daily exercise every improvement which might increase the chances of success against a navy to which we might soon be opposed as an enemy. . . . But the great source of our success was undoubtedly the superior management and direction of our guns; and that the English and other governments were satisfied of this is sufficiently evident by the careful attention they have since continued to give to this branch of the naval service."—Autobiography, p. 166.

† Jones's report, Naval Monument, p. 16.

‡ Naval History, vol. 5, p. 112.

§ Gold's Naval Chronicle, vol. 29, p. 76.

one hundred and ten. For the difference in the vessels themselves, the Wasp was heavier than the Frolic; added to which, in a violent gale the day before, the Frolic had carried away her main-yard, lost her topsails, and sprung her maintopmast; so says Capt. Whinyates' report. These accidents had a direct effect upon the engagement.

At about eleven o'clock in the morning, the Wasp bore down for the Frolic; the Frolic waited to receive her, and opened fire as she came near. After five minutes of close fighting, the Wasp's maintopmast came down, followed presently by her gaff and mizzen-topgallant mast. At the same time the Frolic's main braces were shot away, and she could therefore carry no sail upon her mainmast. This enabled the Wasp to take an advantageous position, and she accordingly stood across the Frolic's bow, with the English ship's jib-boom between her fore and main rigging. In this position the Frolic was boarded by the officers and crew of the Wasp, led by Lieutenant Geo. W. Rodgers; but on gaining the enemy's deck they found no one to oppose them but a handful of wounded officers and men. No resistance was made, and the Frolic's flag was lowered by James Biddle, the first lieutenant of the Wasp.

In this engagement, whatever disadvantages the Frolic may have been under at the start, her casualties were wholly out of proportion to them. She was much injured in her hull, and both her masts fell immediately after the action. She had fifteen killed and forty-seven wounded, some of them mortally; while the Wasp had only six killed and five wounded. The action was fought in a heavy sea, under very little canvas; but even so, the precision of the American gunnery was far superior to that of the enemy. It is said that the Americans fired as the engaged side of their ship was going down, and the English as theirs was rising; which explains, in some measure, the difference in the damage each received and inflicted. Soon after the engagement both ships were taken by the Poictiers, a seventy-four, which came in sight before any preparations for flight could be made.

On the 8th of October, Commodore Rodgers left Boston with the same vessels he had commanded before, except the Hornet. These vessels were the frigates President, United States, and Congress, and the brig Argus. On the 12th, the United States and Argus separated from the squadron, themselves going different ways. The Argus cruised for three months in the north Atlantic, took a few prizes, and

returned to New York early in January. The President and Congress were peculiarly unfortunate in meeting few merchantmen, and they returned to Boston on the last day of the year, having made only two captures in the three months.

When the United States, under Captain Decatur, left the other vessels, she cruised to the SE, and on the 25th of October, at sea, some distance to the west of the Canary islands, she fell in with the British 38-gun frigate Macedonian, Capt. Carden. The difference in the relative force of the ships was even greater than in the case of the Constitution and Guerrière, as the United States had 42-pounder carronades instead of 32's, and on the other hand the Macedonian lacked two of the Guerrière's long 18-pounders, and their place was supplied by 9's or 12's.* When the ships first sighted each other, at daylight, they were twelve miles apart, the Macedonian going before the wind, and the United States to the north of her; the wind was SSE, and the United States was close-hauled on the port tack. In this way they gradually neared, but at 7.30, Decatur, uncertain as to the force of the enemy, wore and stood off. The Macedonian continued on her course, and would soon have overtaken

* The armaments of the two ships were as follows:

UNITED STATES: 478 men.

No. of guns.	Weight of shot.
32 long 24-pounders	768 pounds.
22 42-pounder carronades	924 "
1 18-pounder carronade	18 "
55	1710 "

MACEDONIAN: 297 men and boys (James); 306 (Emmons).

28 long 18-pounders	504 pounds.
2 " 12-pounders	24 "
2 " 8-pounders	16 "
16 32-pounder carronades	512 "
1 18-pounder carronade	18 "
49	1074 "

All accounts agree substantially in regard to the armament; the main point of difference being in the omission by American authorities of the 18-pounder carronade on board the United States. Its presence is asserted by Capt. Carden in his report, and as there is no authoritative statement to the contrary, it is placed in the table.

her opponent, when the latter wore again with a view to closing. At this point, according to the English historian, Captain Carden should have kept on his course and run across the bow of the other ship (as indicated by the heavy line in the diagram), and he was advised to do so by his lieutenant. But he preferred to keep the weather-gage, and passing to windward of his antagonist, they exchanged the first broadsides at 9 o'clock. The Macedonian now wearing followed her opponent on the same tack, and at 9.20 came up with her quarter; at this point the fight may be fairly said to have begun. The first broadsides carried away the mizzen-topgallant-mast of the United States, and the mizzen-topmast and gaff-halliards of the enemy; this produced an equality in sailing, and enabled the United States to oppose the guns on her quarter to those on her enemy's bow in a running fight. The diagonal fire from the United States proved very effective, but at 10.15 she backed her main-topsail and allowed the enemy to come up with her.

As soon as the ships were abreast, there began that tremendous disabling fire of the Americans which had been the main element in their previous successes. In the course of half an hour the Macedonian's mizzen-mast was shot away, her fore and main-topmasts gone, what was left of her masts and rigging badly cut up, her upper battery, with the exception of two guns, disabled, one-third of her crew killed and wounded, and one hundred shot in her hull. The English fought with great bravery and tried to get on board the United States, but the ship would not answer the helm. The fight was now practically over, but the supply of filled cartridges on board the United States having given out, she drew off, refilled her cartridges at leisure, tacked and returned to a commanding position on the stern of the enemy, who immediately surrendered.

In this action, the same facts are noticeable as in the earlier engagement, but in a more marked degree. The odds at the start are strongly in favor of the Americans, in the size and strength of the ships, in the number and still more in the weight of the guns, in the number of men. The English tactics are bold, dashing, more so than in the action of the Guerrière; the English captain manœuvres carelessly and neglects his advantages. The Americans, on the contrary, mindful of their "pigmy navy," as the English papers called it,* and the great loss to the country that would follow the destruction of a

* Nav. Chron. 29, 198.

single frigate, are wary and cautious to such an extent as almost to decline an engagement, and to lead their enemies to charge them with cowardice: a charge which no one certainly could more easily repel than Decatur. The accurate and careful gunnery of the Americans and the great rapidity of their fire quickly disable the enemy, carry away his masts, shatter his hull, silence his battery; while in return he inflicts little or no injury. The inequality in the loss of men is still more striking. The Americans have only seven killed and six wounded; while the English loss foots up to the comparatively enormous total of thirty-six killed and sixty-eight wounded. As in the capture of the Guerrière, the American ship hauls off when the engagement is practically at an end, to renew her preparations, and after attending to these matters at her leisure, she only returns to receive a final surrender.*

Not long after the beginning of the war the government had resolved to send a squadron to the south Pacific, to destroy the unprotected British commerce in that quarter. With this object, on the 27th of October, shortly after the capture of the Macedonian, the Essex, still under Captain Porter, left the Delaware, and a few days later the Constitution, now commanded by Captain Bainbridge, and the Hornet, Captain Lawrence, left Boston. The ships were to rendezvous at Bahia, and other ports on the Brazilian coast. As is well known, the Essex missed the other ships, and went on the intended cruise alone. The Constitution and Hornet reached Bahia near the end of December, and the Hornet was sent in, Commodore Bainbridge remaining alone in the neighborhood of the coast.

On the 29th, at 9 o'clock in the morning, as the Constitution was sailing by the wind on the port tack, the wind being from the NE, two vessels were seen in the NNE. These were the British 38-gun frigate Java, Captain Henry Lambert, and an American merchantman, a prize of the Java. The prize was cast off and sent into Bahia, but before her arrival was recaptured by the Hornet. The Constitution tacked, and the two opposing vessels now stood for each other; but after a time the Constitution, finding her signals unanswered, went about and stood to the southeast, to draw the Java away from her companion, which in the distance Bainbridge mistook for a ship-of-war.

About noon the Java hauled up, steering a course parallel to the Constitution. As the morning passed away she came rapidly up, and

* Captain Carden's report, Gold's Nav. Chron. vol. 29, p. 77; Commodore Decatur's report, Nav. Mon. p. 24; James, Nav. Hist. vol. 6, p. 114.

was made out to be an English frigate. At 2 P. M. the two ships were within half a mile, the Java to windward, and the firing began. They were both sailing by the wind, in the same direction as that of the Constitution, when the enemy was first sighted. At 2.20 the Constitution wore to avoid being raked; the Java wore also, and the ships being again side by side on the starboard tack, exchanged broadsides, by which the wheel of the Constitution was entirely shot away. Again the Constitution wore, and the Java, performing the same manœuvre, at 2.35 passed just astern, and missed an excellent opportunity of raking her opponent. At 2.40 she again passed the stern of the Constitution, and this time fired a few guns. Immediately after, the Constitution luffed up close to the Java, and for a few minutes the action was spirited; here the head of the Java's bowsprit was shot away. At 2.52 the Constitution wore again, and the Java, as the quickest way to get about, tacked; but after coming up in the wind, she paid off very slowly, from the want of head-sails. As she was in the midst of this operation, the Constitution, seeing her opportunity, luffed up astern of her and gave her a raking fire; then wearing again, she resumed her course, and the Java once more got alongside. Here the decisive part of the engagement began. At eight minutes after 3, as Captain Lambert, foreseeing the inevitable result, was preparing to board, and with that view was bearing up towards the Constitution, the Java's foremast fell and prevented the attempt. At 3.15 the Constitution wore across the Java's bows, and brought down her maintopmast; then luffing up to leeward of her, poured in, first her starboard, and then, wearing, her port broadside. Remaining alongside in this last position, she continued a heavy fire, carrying away the gaff and spanker, and finally the whole mizzenmast. Before this, Captain Lambert had fallen, mortally wounded, and the command of the Java devolved on Lieutenant Henry Chads, who still continued bravely defending her. Soon after four, her fire ceasing and all her flags being down, Bainbridge supposed she had surrendered; and then he performed that manœuvre which we noticed in the actions of the Guerrière and the Macedonian, of hauling away from his disabled enemy and leisurely repairing his own injuries. From the remarkable similarity in the method of the three captains, Hull, Decatur, and Bainbridge, one might almost suppose it was a regulation of the department. As in the other cases, Bainbridge returned in about an hour, and took up a raking position, only to receive the formal surrender of his adversary.

It is hardly necessary to go over all the points of resemblance between this case and the other two,—points upon which we have already dwelt at length. The relative force in guns was about the same as in the fight with the Guerrière; while the crews were more nearly equal, owing to the presence on board the Java of a large number of supernumeraries. As far as one may judge from conflicting statements, there were about four hundred and eighty officers and men on board the Constitution, and about one hundred less on board the Java. The difference in the killed and wounded was very great, the Java having twenty-two killed and one hundred and two wounded; while the Constitution had only nine killed and twenty-five wounded. At the close of the engagement, the Java was such a wreck that she could not be carried into port; while the Constitution, though she gave up her cruise in the Pacific, had no difficulty in returning to the United States.*

After the departure of the Constitution, the Hornet remained off Bahia, blockading the English sloop-of-war Bonne Citoyenne, which was lying in the harbor. After three weeks thus occupied, she was driven off by the arrival of the 74-gun ship Montague. She now cruised for some time off the coast of Brazil and Guiana, and captured two valuable prizes. On the 24th of February, at the entrance of Demerara river, the Hornet discovered a vessel-of-war on her weather quarter, edging down for her. This was the English brig Peacock, commanded by Captain William Peake, and mounting sixteen 24-pounder carronades and two long 6-pounders. The Hornet, as soon as she made her out to be an enemy, cleared for action, and kept close by the wind, to get the weather-gage. This was some time after four o'clock in the afternoon. At ten minutes after five the Hornet tacked and passed close to windward of the enemy, the two ships exchanging broadsides. As the Peacock wore after passing, the Hornet bore up, received the starboard broadside of the enemy, ran him close on board his starboard quarter, and kept up such a heavy and direct fire that in less than fifteen minutes he surrendered; "being literally cut to pieces," as Lawrence says in his report. Immediately afterward the mainmast of the Peacock fell, and a signal of distress was hoisted. It was found that she was sinking rapidly, having then six feet of water. Every effort was made to save her, and the prisoners were taken off as quickly as possible; but before the work was fin-

* Bainbridge's report and journal, Nav. Mon. pp. 28, 32; Lieutenant Chads' report and address to the court, Gold's Nav. Chron. vol 29, pp. 346, 403.

ished, she went down, carrying with her thirteen of her crew and three men from the Hornet. Captain Peake and four men were killed in the action, and thirty-three wounded. The Hornet lost only one killed and four wounded,—two of the latter by the bursting of a cartridge. Her rigging and sails were somewhat cut, but her hull had little or no damage. It was, like most of the others, a victory over a somewhat inferior force, in that the Hornet was armed with 32-pounders against her opponent's 24's; but it was a victory of a remarkably quick and successful character.* The Hornet immediately sailed for home, and arrived at Holmes' Hole on the 19th of March.

Besides the Wasp and the Nautilus, only two vessels of the navy had been captured during this period. One of these was the brig Viper, captured by the British 32-gun frigate Narcissus, in January, 1813. The other was the brig Vixen, so closely associated with the Nautilus in Preble's operations against Tripoli. Both vessels were built or bought in 1803, and both were altered from schooners to brigs in 1810. The Vixen carried twelve 18-pounder carronades and two long 9-pounders. At the time of her capture, Nov. 22, 1812, she was cruising among the West India islands, under the command of Master-Commandant George W. Read. She was taken by the British frigate Southampton, of 32 guns, commanded by Sir J. L. Yeo, after a chase in which every effort had been made to escape. Soon afterwards, both vessels were wrecked on one of the Bahama islands.†

As no further engagements of any consequence between national vessels took place until the action between the Chesapeake and Shannon in June, we may say that the events related comprise the first year of the naval history of the war. What had been the results? During this period, the navy had captured in single engagements three frigates and three brigs or sloops-of-war. At the outbreak of the war

* Possibly there was a considerable disparity in men, as well as in weight of metal, between the two ships. Emmons places the force of the Hornet at one hundred and thirty-five men, and that of the Peacock at one hundred and thirty. James makes the respective complements one hundred and sixty-five and one hundred and twenty-two. But as neither of these writers quotes any authority, it is hard to say which is correct. Lawrence in his report (Nav. Mon., p. 38) says that the Peacock's crew, according to her quarter-bill, consisted of one hundred and thirty-four men, four of whom were absent on a prize; but I have met with no authentic statement of the Hornet's complement. As Admiral Emmons had access, however, to the files of the Navy Department, his statement must be accepted as the most trustworthy that we have.

† Nav. Mon., pp. 215, 227.

we had six frigates and eight small ships or brigs in commission; while upon the coasts of America were three squadrons of the enemy, any one of which was a match for all of ours. On the Halifax station there were twenty-four vessels, frigates and brigs, not counting the schooners; on the Jamaica station twenty-two, and among the Leeward islands seventeen.* And all that this immense force, more than three times the size of our own, could accomplish was the capture of one sloop-of-war, the Wasp, disabled after an engagement, and three diminutive 12 and 10-gun brigs, one of which was taken by a squadron. The results more than justified the cautious tactics of our officers. It was only in a wise husbanding of resources that any result was attained; here lay the secret of an end so marvellously disproportionate to the means.

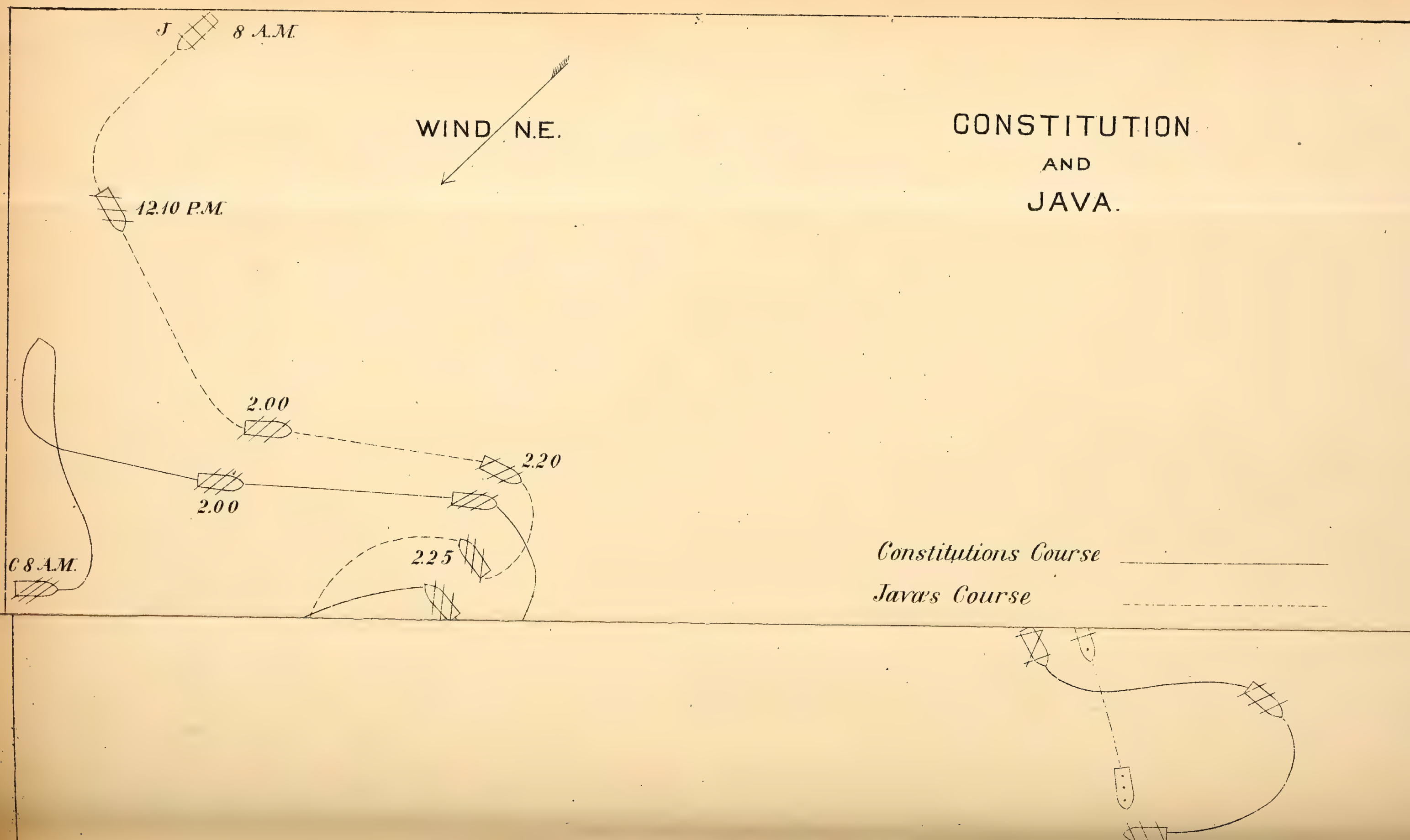
To the results of the great engagements must be added the vast number of merchantmen made prizes by privateers as well as by national cruisers. Of these over four hundred and thirty were reported in this first year, without counting recaptures, of which there were a great number. This was a loss that touched the enemy more materially, at the moment, than the capture of six men-of-war, in a navy whose ships were counted by hundreds. It was only the moral significance of the great sea-fights that made them so important. For twenty years, English ships had been accustomed to victory over every enemy, even in the face of heavy odds. The nation looked upon them as invincible. Upon its maritime superiority the government based pretensions which, if admitted, would have made commerce an English monopoly. Englishmen only knew of American policy and American armaments to despise them; and when the war broke out, it gave them little concern, and it was the intention of the government to prosecute it at leisure in the enemy's country. The capture of the Alert was looked upon by English officers as an accident, a thing of no moment, which was only to precede the extinction of the little American navy. The loss of the Guerrière astonished them for an instant, and served, at least, to establish the fact that the Constitution was something more than a "bundle of pine-boards, under a bit of striped bunting," as she had formerly been called in derision. But as loss followed loss, and capture followed capture, as they saw the Frolic, the Macedonian, the Java, and the Peacock successively taken, the revulsion of feeling was tremendous. The journals and magazines were filled with letters and

* Niles's Reg., 2, 356.

essays, with minute calculations aiming to show the enormous advantage possessed by the vessels they had derided. The naval administration was attacked, and called upon to take more energetic measures. Ships-of-the-line were razeed for the express purpose of fighting the President and the Constitution to advantage, and the squadron on the American coast was reinforced by some of the most powerful ships in the navy. As a Boston paper wittily put it, the English, in the spring of 1813, were sending out frigates to America under convoy of line-of-battle ships. But the most important effect of American victories was to show the hollowness of English pretensions to the control of the ocean. In view of the possibilities of future wars, it was idle any longer to advance the theory so arrogantly put forth by English writers, that "the frontier of England was high-water mark on every shore, and the British seas were wherever a 32-pounder could be floated."*

The course of events had produced a result no less marked in America. Doubtless in the enthusiasm of the moment, circumstances were exaggerated and distorted; but however they might be presented, the fact remained that American ships had beaten their enemies. The navy suddenly became the most popular branch of the public service; and its popularity was redoubled by comparison with the reverses of the army, whose campaigns in the north had been one long series of almost uninterrupted disasters. The war party, the party of the democratic republicans, was now only too ready to pet and patronize the navy, which it had hitherto so steadily opposed; while the justification of the "high federal measure" of former years half reconciled the federalists to the war. As the news came of victory after victory, each one so decisive and so unexpected, the most bitter partisan could not help feeling a glow of enthusiasm; and the country at last learned to look upon the navy as its only real protection, as the securest defence of the national honor.

* Gold's Nav. Chron. 29, 198.



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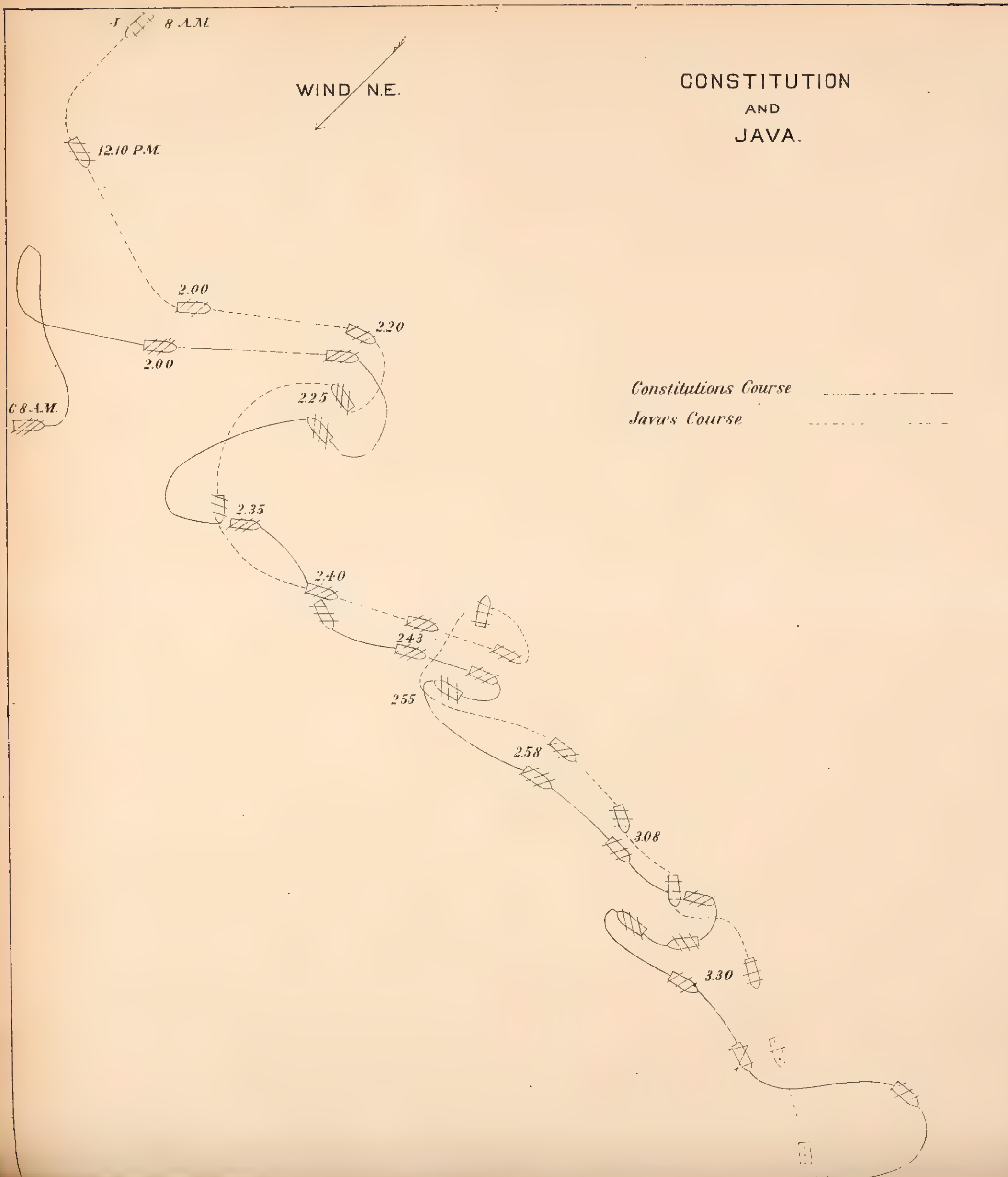

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NAVAL INSTITUTE, ANNAPOLIS, MD.

November 16, 1881.

Commander H. B. Robeson, U. S. N., in the Chair.

THE LEE SYSTEM FOR SMALL ARMS.

By Mr. James P. Lee, President of the Lee Arms Company.

After the muzzle-loading arms collected upon the field of Antietam, found in so many cases to be loaded with more than one cartridge, had shown the necessity of adopting for general military work a breech-loading system which would not allow overloading, after the Austro-Prussian war had demonstrated the superiority of breech-loading small arms, and after the perfecting of metallic ammunition had rendered breech-loading entirely practical, the United States government, in 1872, ordered a board of officers to consider all the breech systems attainable and select one for army use.

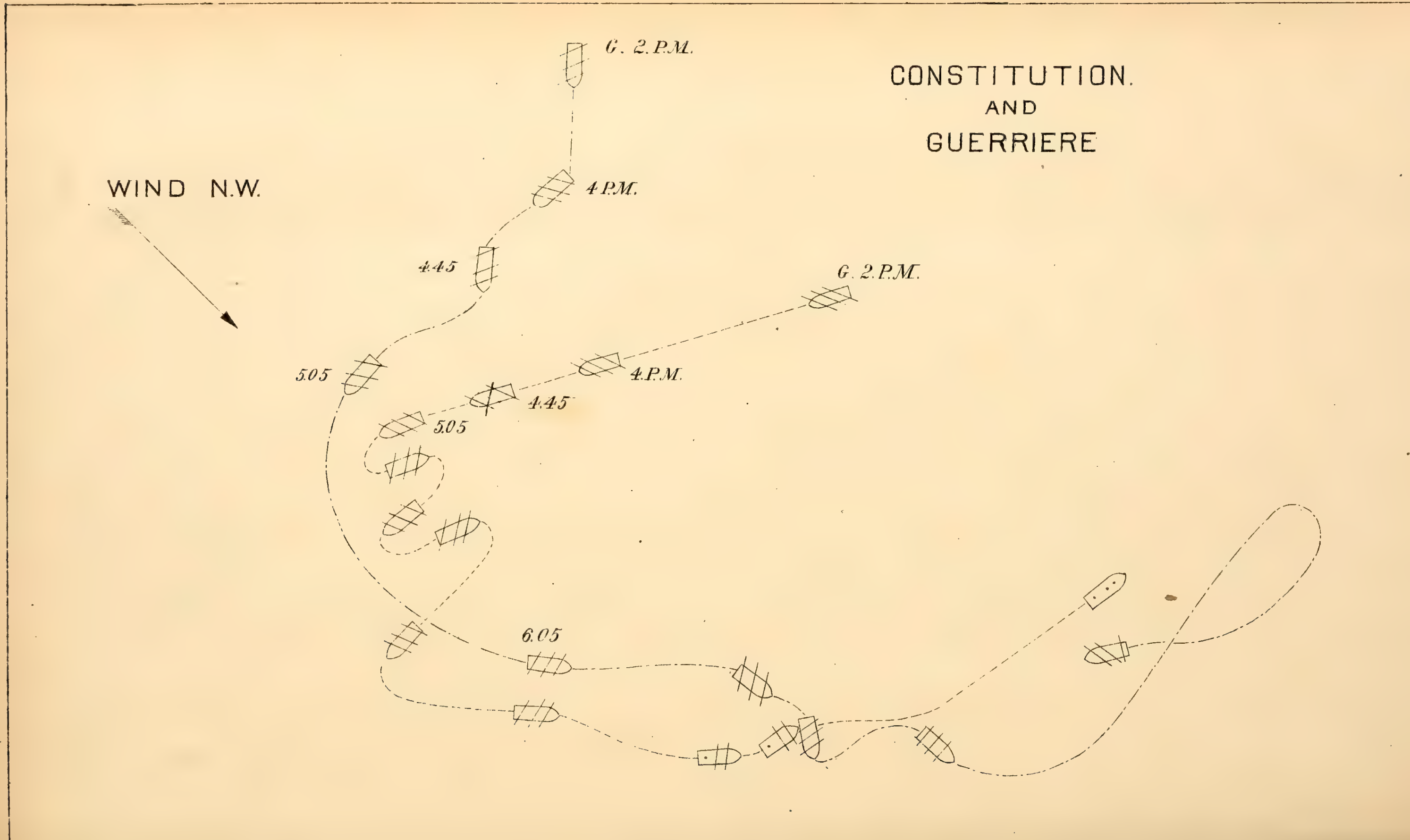
In the report of that board to the secretary of war it was:—"Resolved, That in the opinion of the board, the adoption of magazine guns for the military service of all nations is only a question of time; that whenever an arm shall be devised which shall be as effective, as a single breech-loader, as the best of the existing single breech-loading arms, and at the same time shall possess a safe and easily manipulated magazine, every consideration of public policy will require its adoption."

I have endeavored to produce such an arm, and, after some years of experimenting, have produced an arm whose points I would desire to present to the members of the Naval Institute, leaving it for them to decide how nearly I have fulfilled the wants of the board as expressed in the above-quoted resolution. The general military opinion of the world has decided that the breech-closing mechanism for small arms

shall be of the bolt type, and accordingly for my system I have adopted a bolt in the design of which I have endeavored to attain the requisites of simplicity of construction, strength of system and certainty of action; and have succeeded so far in producing one with fewer parts than any bolt in use, capable of being entirely dismounted and assembled with no other tool than a penknife or an empty cartridge-shell, having no screws about it to jar loose, having a powerful, easy, and certain extraction, and having a long travel to the firing pin, a long mainspring, and the consequent ability to function certainly with comparatively little work on the spring. The bolt lock, functioning when the piece is brought to half-cock, is of such a design that the metal of the bolt must be bodily sheared away before the lock can refuse action. Repeated blows with a mallet upon the bolt handle fail to force the lock even when the arm is held fast in a vise. The receiver is of such construction that the recoil is taken upon lugs that drop below the line of the panel and abut upon shoulders in the stock, "in the straight of the wood," *i. e.* in line with the straight wood through the small. The stock shows no sign of failing when dropped from a height upon the butt plate, or under long continued firing tests. When the magazine is not upon the gun, a bottom to the receiver is formed by a simple device, so that the gun is then a single loader pure and simple, and, it would seem, a weapon that possesses the first requisite demanded by the board, viz., that the arm "shall be as effective as a single breech-loader as the best of the existing single breech-loading arms."

As regards the second requirement of the board—"and at the same time shall possess a safe and easily manipulated magazine,"—I have endeavored to make the magazine *safe* by so arranging it that, when charged, the cartridges it contains can in no way receive a dangerous shock upon the primers, either by blows or by concussion due to recoil; and I have attempted to make it "easily manipulated" by so designing it that the manipulation consists in slipping a $3\frac{1}{2}$ ounce steel box into a free slot, pressing it home, or driving it there with a tap of the hand; and touching a catch conveniently placed in the trigger-guard before withdrawing from the slot. It is submitted that in the present condition of arms-making it is hard to conceive of an easier manipulation.

The charging of the magazine consists in pushing in the required number of cartridges, one on top of the other laterally, not one before or behind the other as in tubular magazines. An ordinarily intelli-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gent man will charge a magazine containing five cartridges in as many seconds, while he will find it impossible to get in a cartridge in a wrong position for feeding up. The magazine is detachable, and being detachable, it can be lost. This is an apparent disadvantage of the system, but in deciding whether or not it really be so, I would ask consideration of the following propositions: If it be non-detachable, the arm cannot fulfill the first requirement of the board's resolution, and "be as effective as a single breech-loader as the best of the existing single breech-loading arms"; for an attached magazine implies the increased weight of arm due to the charged magazine —which must be kept charged to be always ready for the "critical moment," for which magazine fire is wanted—and a complication of parts in the necessary "cut off" device by which the magazine charge can be held in reserve. The magazine of my system is no more and no less detachable than is the cartridge, and when charged may be considered as a cartridge capable of delivering five rounds and of being as easily placed in the gun as is the single one, while it would seem from its size and shape not so readily dropped and lost. Each man may be provided with such a number of magazines—four or five—that the loss of one or two will not disable the gun as a magazine arm; if all the magazines be lost the gun is still an effective single-loader that cannot be disabled by accident to the magazine parts; the magazines are so inexpensive that the loss of them is financially small, and almost inappreciable in comparison with the advantage of having no "cut off" to confuse the men at the "critical moment." Finally, the magazine catch can be permanently locked and the magazine thus made a detachable one.

If, as is generally conceded, the small-arm fire in the naval actions of the future is to be poured in as rapidly as possible during the few seconds of the struggle for a close action, my system would seem to be well adapted for naval uses; for the small-arm men on deck could be provided with five or six charged magazines,—in loops or pockets on the waist belt,—that could be emptied against the enemy with great rapidity, while the riflemen aloft, provided with a small chest filled with charged magazines, in each top, would be unencumbered with belts and cartridge-boxes when needed for duties in the rigging. For landing, the men could be provided with an allowance of ammunition in the ordinary cartridge-box for single loading use, and hold in reserve the charged magazines in pockets on the left side of the waist belt.

Lt. Mason: During Rear Admiral Stevens' last inspection of the Wachusett on the Pacific station, I was ordered to pay particular attention to the repeating arms with which the riflemen of her crew were armed. I found that very few of the men, although otherwise they showed themselves to be well instructed, could explain or use the cut-off when flurried by the excitement incident to the inspection. Such a thing in action, where the excitement would have been much greater, would have entirely neutralized the benefits of the firearm, if they had not actually rendered it objectionable.

I am in doubt whether any but good shots should be armed with repeating or magazine arms, although on some occasions, notably at Plevna, they have proved invaluable when not aimed at all. For the good shots I think that a very rapid firing many cartridge magazine gun is the proper arm, and, especially for ship work at the moment of ramming or passing. The Lee gun with its easily interchangeable magazine would seem to meet our wants, especially if the supply of filled magazines at hand were large. Under most circumstances a few good shots, well provided with filled magazines, capable of directing their fire to many parts of an enemy, would be more effective than a small bore machine gun.

During the war between Chile, and Peru and Bolivia, several events showed how a power to greatly increase small-arm fire at any moment was most effective and an inability to do so was fatal. Had Pratt and Lerano had magazine arms when they boarded the Huascar from the sinking Esmeralda, the result of that battle might have been changed, as but few of the Huascar's crew were prepared to resist even the handful of boarders.

The small-arm fire from the twelve men in each of the forward tops of the Chilian ironclads at Angamos was so well sustained that they drove the crew away from the Huascar's gatling in her top, and caused it to be currently reported that instead of riflemen they were machine guns.

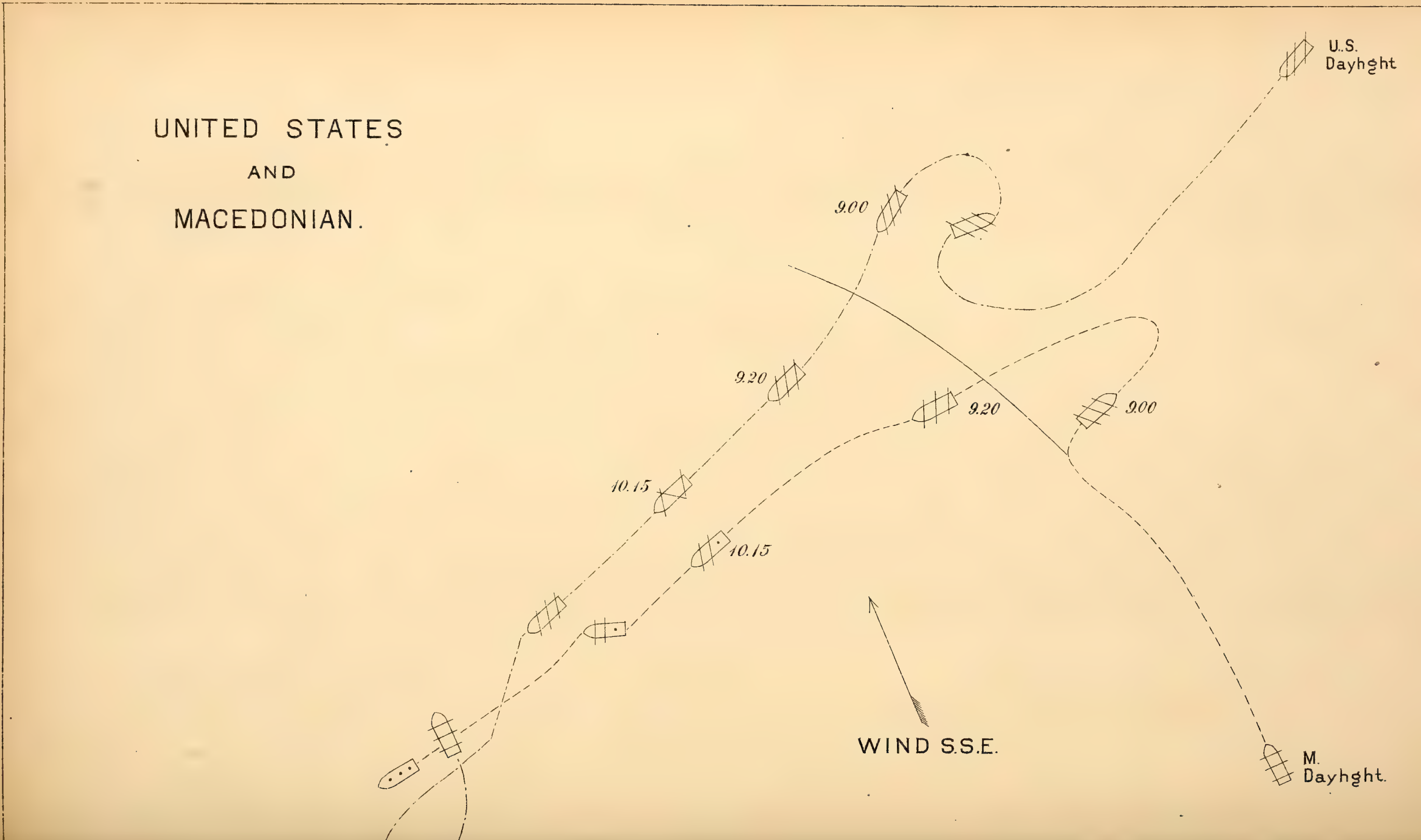
The Germans have adopted a detachable magazine gun, somewhat similar to the Lee, and seem to be well satisfied with it both in their land and sea services.

The French have a repeating rifle, and are not entirely pleased with it in the hands of troops, and especially in those of sailors.

Lt. Comdr. Thomas: I would like to call attention to the greater facility of aiming with the Lee gun than with any other magazine gun yet proposed. The position of the magazine is well placed for nicely balancing the weapon, and the center of gravity is not materially altered as the magazine becomes exhausted.

The Chairman: I have listened to the reading of this paper with much interest; especially as it appears to me to involve a new principle in the construction of repeating arms.

The principle to which I allude is in the position of the magazine, which in the Lee repeating rifle seems to reduce to a minimum, if not to entirely obviate the very serious objection of the derangement of aim, and consequent want of accuracy, resulting from a constant change of the center of gravity of the piece on the emptying of the magazine. As this subject has already been spoken of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this evening, I will pass to one or two other points which appear to be worthy of attention.

One notably distinctive feature of this arm is in the attachment of the magazine, which is entirely separate from the gun, so that the piece may be either used as an ordinary breech-loader or used as a repeating arm. In other systems of repeating rifles the magazine is charged by introducing the cartridges one by one; in this system, the whole magazine is attached with the same facility with which a single cartridge can be charged. In other words, the gun either fires one or five rounds, and loads both equally well.

Apart from these distinctive features, the gun appears to be simple in its mechanism, and in this respect seems to be particularly adapted to the wants of general service.

PLATE I.

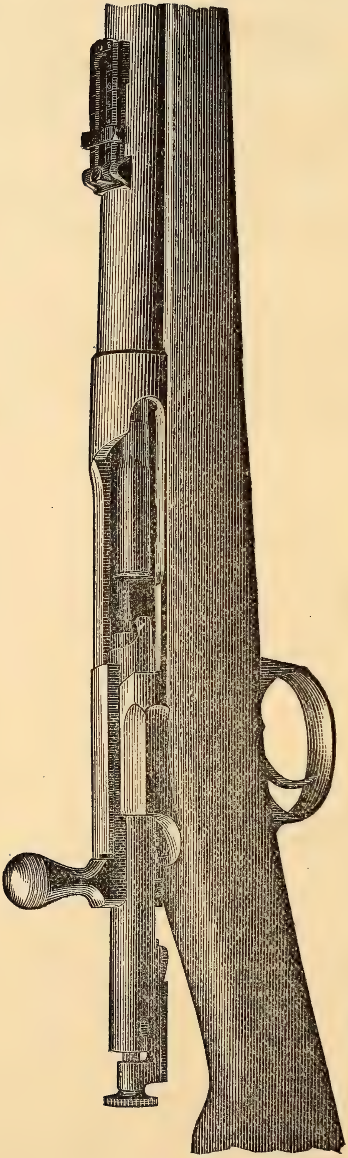


Fig. 1.

Lee System Open, with Magazine Detached.

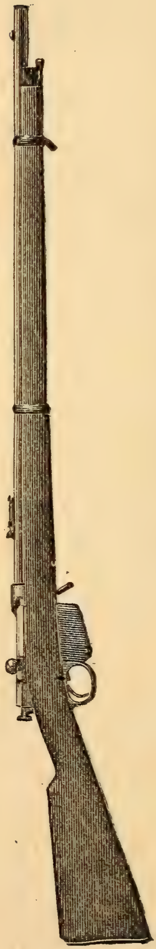
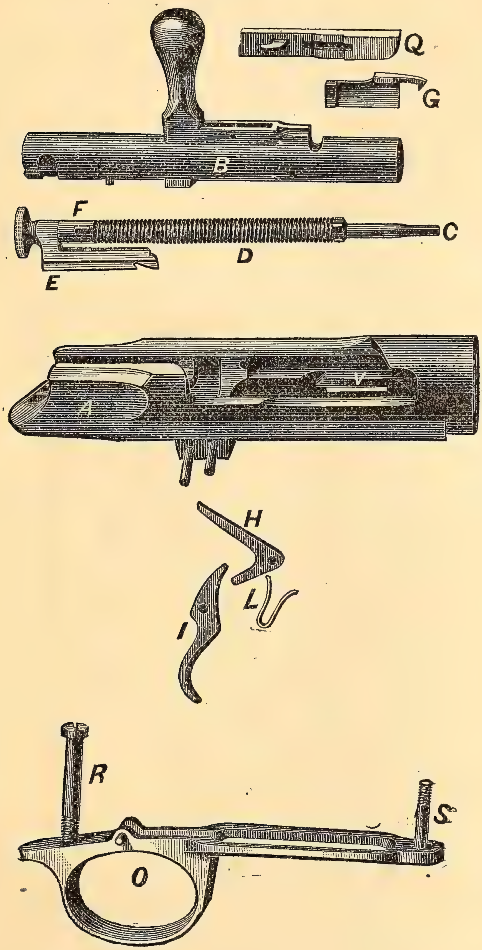


Fig. 2.

Lee Military Rifle, with Magazine in place.
Weight, nine pounds.

PLATE II.

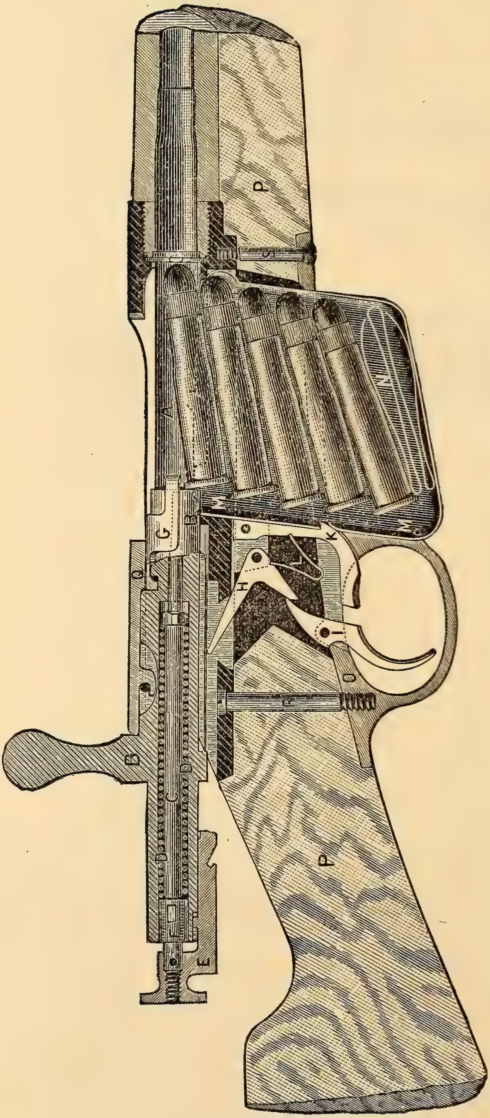


Component Parts of the Lee Bolt System, without Magazine Mechanism.

A. Receiver.
B. Bolt.
C. Firing Pin
D. Main Spring.
E. Thumb Piece.
F. Key Sleeve.
G. Extractor.
H. Sere.
I. Trigger.
L. Sere Spring.
O. Guard.
Q. Extractor Spring.
R. Tang Screw.
S. Guard Screw.

PLATE III.

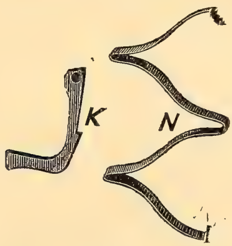
Sectional View of Lee System, with Magazine in place.



A. Receiver.	F. Key Sleeve.	L. Sere Spring.
B. Bolt.	G. Extractor.	M. Magazine.
C. Firing Pin.	H. Sere.	N. Magazine Spring.
D. Main Spring.	I. Trigger.	O. Trigger Guard.
E. Thumb Piece.	K. Magazine Catch.	P. Stock.
R. Tang Screw.		S. Guard Screw.

PLATE IV.

Weight of Magazine and Spring, $3\frac{1}{2}$ ounces.



MAGAZINE MECHANISM.

Component Parts.

K. Magazine Catch. N. Magazine Spring.

M. Magazine.

The Spring W serves to form a cover or bottom to the Receiver, while the arm is used as a Single Loader.

PROFESSIONAL NOTES.

These articles have not been read before the Institute, but are inserted by direction of the Executive Committee.

DIFFERENT TYPES OF CIRCULATING PUMPS FOR SURFACE CONDENSERS.

Few who have experience in the care and management of the old-fashioned circulating pumps driven directly from the steam piston rods, and with independent pumps as now applied, will hesitate in their preference for the latter.

The following comparison of the two systems as applied to the Alaska and Despatch may be of interest to some:

	Alaska.	Despatch.
Number of cylinders	2	2
Diameter	50″	33″
Stroke of Piston	42″	33″
Diam. of circulating pump	18″	Centrifugal, driven by independ't steam cyl. 12 in. di. and 8 in. st., 130 re. per m.
Stroke " "	42″	
Indicated horse power	523.8	542.1
Pressure at release, (absolute)	13 lbs.	17 lbs.
Mean back pressure	3.25	6.2
I. H. P. of pump cards	35.09	
" " independent engine		2.29
Per cent. of power absorbed by circulating pump	6.69	0.41
Square feet of condensing surface.	2465	1165
Cross area through tubes	188sq in	198 sq. in.
Temperature of injection	64°	45°
Temperature of discharge	84°	79°
" " feed	136°	120°
Foot lbs. of work expended on pump per thermal unit removed.	5.93	0.42

In the case of the Alaska, only the work done on the water is accounted for, so that really 35.09 I. H. P. should be increased to about 42. I. H. P., which would show still worse for the Alaska. On the other hand the Alaska was running at half power and the Despatch at full power.

CHARLES H. MANNING,
P. A. ENGINEER, U. S. N.

A NEW SPEED INDICATOR.

The speed indicator consists of a combination of three independent parts, viz. an instrument for creating a vacuum, a long flexible tube for communicating the vacuum to a gauge on deck, and the vacuum-gauge itself. The instrument for creating the vacuum (in itself old) is founded on the principle discovered by Bernoville in the sixteenth century, that water flowing through a cylindrical mouthpiece contracts its vein at a distance of about one-half the diameter of the cylinder from its entrance, and that at the point of greatest contraction a partial vacuum is produced. Further, that the vacuum varies as the square of the velocity of the water, and that it is immaterial whether the water flows through a stationary tube, or whether the tube is hauled through the water, the latter remaining stationary.

To obtain a more perfect vacuum, I use, instead of an ordinary cylinder, a combination of conical tubes about one foot long, made of sheet brass, shaped like a dice-box, and so constructed that a high velocity is produced at the contracted part. Around the circumference of the tube, at equal distances from each other, are three small brass pipes which enter the vacuum instrument at the most contracted part, whence they converge symmetrically to a point some distance in front of the mouth of the tube and in the prolongation of its axis.

The vacuum instrument is kept at a mean depth in the water by means of a float, which is towed by a wire leading from a collar on the flexible tube; the float is over the instrument and connected to it by means of a wire. The flexible tube is of hard rubber, three-eighths inch external and one-eighth internal diameter. To protect it from chafe and wear, fine copper wire is braided over the outside and blended with it by heat. Through the centre is rove a stout copper wire making fast to the ferules by which the sections of the tubing are joined together; by this means the tubing is made as strong as an ordinary log-line. The length of the tubing varies with the vessel; for yachts fifty feet are required; for boats, fifteen feet; for small steamers, one hundred feet, and for large steamers, two hundred feet. The tubing may be astern or alongside; but it must be rigged out from the side so as to be clear of the eddies.

The flexible tube fits over the top of the gauge on deck; the latter may be of any type, but the mercurial gauge is preferable for many reasons. The glass tube of the mercurial gauge is drawn down to a very fine opening to throttle and regulate the fluctuations of the mercury; the gauge is suspended like an ordinary sea barometer, and is fitted so that when not in use the tube is protected from injury.

In all instruments hitherto, in which the speed has been indicated by a vacuum, the vacuum instrument has been rigidly connected to the vessel. The objections to this are that the ship by friction always carries along with it a large body of water, and in rolling the tube is carried to different depths; both causing incorrect indications. There is also the practical objection that if the instrument becomes fouled it is difficult to get at it to clear it.

In using the indicator, the vacuum instrument is thrown overboard and the flexible tube paid out from a reel on deck; when it is out to its full extent, the strain is taken by a wire extending from a collar on the tube near the rail to a stanchion on deck. The resistance offered by the instrument being small, it does not come to the surface, while its conical opening and the flow of water through it serve to steady it. The tube is then connected to the gauge, when the mercury will immediately rise till it attains a height due to the speed of the vessel through the water.

When tried on board the Alarm, with a speed of eleven and three-quarter knots (the highest attained), the height of the mercurial column was nine inches; the fluctuations amounted to only one quarter of a knot at the most, and generally the mercury was steady. No doubt with better apparatus the results will be improved. The higher the speed with the same fluctuations, of course the smaller the error; on account of the increased distances on the scale. In smooth water the instrument will show a speed of one knot, equal to a height of one-eighth of an inch of mercury. The advantages of its use in sailing vessels are especially apparent, as the effect of any sail may be known in a moment.

Chief Engineer Isherwood, in a personal report to me, signed also by Chief Engineers Zeller and Magee (the experimental board), says, "We are of opinion that this instrument, when properly constructed and adjusted and correctly graduated, will give the vessel's speed reliably and to a closer reading, owing to the sensibility of the mercurial column, than any of the patent logs known to us. It is so simple that its use may be entrusted to the least intelligent, and there is nothing in its construction liable to derangement. The above statements are warranted by the practical test to which we saw the instrument subjected on board the Alarm during the experimental trials of that vessel in the Hudson river."

W. S. HOGG,
ENSIGN, U. S. N.

REVIEWS.

No publication will be noticed under this head, unless a copy, to be placed in the Institute library, is sent to the Corresponding Secretary at Annapolis, Md. Reviews must be signed by the writer.

CAPTAIN ERICSSON'S SUBMARINE TORPEDO SYSTEM. *American Machinist, Sept.* 24, 1881.

In arriving at his present torpedo system Capt. Ericsson seems to have advanced through the stages of a compressed air motor, directable torpedo, an overthrow diving projectile, to the true submarine gunpowder projectile, one which, as regards means of projection, for years has been the dream of torpedo men.

He seems to have satisfactorily proved that the gases of exploded gunpowder can be used to eject a torpedo, and that the torpedo shall have a practical velocity through the water—enough at short range to strike a rapidly moving ship's hull. The method is so simple and natural that it is only by remembering the difficulties that have baffled others when working in this line that we can appreciate what has been done.

The Whitehead is perhaps the only auto-mobile torpedo that can be said to have had a career; and that is a complicated machine, carrying its own power and utilizing it through engines, propeller, etc.; the power must be stored through use of an air compressor, and must be worked off properly through the engines. Ericsson stores enormous power, always ready for application, in a powder tank in the magazine and brings it into use by applying fire. When the Whitehead torpedo is fitted with a cable and electric steering gear, as in the one intended for cruising between the forts at Spithead, it is no longer a true auto-mobile, but a directable torpedo, and it must then compete with the Lay and Scott-Sims, and others of the class.

But, considering both the Whitehead and the Ericsson as projectile torpedoes, the question arises, can the Ericsson do all that is claimed for the Whitehead? To this we must answer that we don't know;

but this we do know, that the Destroyer, steaming seventeen statute miles per hour, with a powder charge of twelve lbs. prismatic, fired its torpedo through three hundred and ten feet of water in three seconds, the length of the projectile being twenty-five feet and six inches, diameter sixteen inches, and weight, including explosive charge, fifteen hundred pounds; and retained a large safety margin as regards pressure in the chamber of its peculiar-looking gun. When these points were determined, Capt. Ericsson "was glad to terminate his experiments on account of the great risk an individual runs who ventures to experiment with guns and gunpowder without governmental authority, thereby exposing human life on his own responsibility."

He does not propose to stand off at long taws for torpedo work, but to run as close to the enemy as he possibly can—three hundred feet—and at the same time avoid ramming; his idea seems to be to close, try a torpedo shot, back, hard over helm, go around and try again if unsuccessful at first; and this is one of the best points of the system—the ease with which the gun can be reloaded for another shot. The torpedo room of the Destroyer takes nine projectiles, which can be placed in the gun and fired in quick succession.

At first glance at the system as shown in the *American Machinist* of September 24th of the current year, the idea that the firing pin of the fuse must push through the temporary valve or tompion while it is in the muzzle of the gun is rather disagreeable, especially if one make a personal application and imagine himself in the pilot-house over the gun when it is fired; but upon looking into the construction of the fuse and tompion, and considering what a large safety margin there may well be between the power needed to force off the india rubber covering of the firing pin-hole and that needed to compress the spiral spring whose duty it is to keep the pin clear of the primers, the sense of danger diminishes rapidly. It may be considered axiomatic that in all torpedo work one takes chances; but this chance of disaster through premature explosion in the gun seems really very small. The tompion enables the torpedo to start in air instead of in water—a very apparent advantage; but the air must be greatly compressed as the projectile moves forward; and it would perhaps force out the tompion before the firing pin reached it, if the distance traveled through were greater.

The familiar example of bursting a gun-barrel by placing a paper wad in the muzzle and loading with an ordinary charge, tells us by comparison what an enormous pressure there would be in the bore

did not the projectile so nearly fill it. Under the present conditions, experiment has shown that this pressure is not inordinate. From the arrangement of the powder charge by central suspension in the large chamber we should expect the small pressures that as matters of fact are found to exist during firing—small as compared with those of super-marine guns, but sufficient to give the huge mass of the torpedo an initial velocity of one hundred feet per second.

In looking through the Destroyer one is impressed by her beautifully compact four-piston rod, one thousand H. P. engines, fitted, of course, with that favorite of Ericsson, an independent air pump; and with the strength and simplicity of the hydraulic steering gear; the small wire wheel ropes have only to work an ordinary three-way cock between two pumps whose function it is to work the rudder, which has no rudder-post head to be shot away.

The man at the wheel sees the object of attack through a sight port cut through the armor at two feet above his head, a pair of inclined mirrors putting an extended field of view under his eyes, and has within reach speaking tubes to the engine and torpedo rooms, as well as the electric firing device.

Realizing its speed, the destructive power it possesses, its defensive power by submersion and by the inclined armor forward, the Destroyer would seem to be rather a comfortable vessel to fight in—comfortable, at least, as torpedo boats go, apart from the fire of the ship attacked bows on, which might be endured for the time necessary for a close. The combination that might make a person aboard her more or less uneasy, however, would be that of other torpedoes, auto-mobiles, projectiles, and even spars in case of closing too much, with plunging machine-cannon fire from an unattacked ship on the quarter.

To a person curious in ordnance details it would be interesting to know what decided Capt. Ericsson in adopting a square lug breech plug instead of the French fermature, and why he has no stop to determine the withdrawing position of the plug; while a seaman might wonder just how, in a sea-way, he was to handle, whip over the side, and ship in their beckets under the bow, the muzzle-loading guns proposed for a ship not provided with a submarine gun in its keelson.

WM. W. KIMBALL, Lieut. U. S. N.

November 10, 1881.

BIBLIOGRAPHIC NOTICES.

ASTRONOMICAL REGISTER.

JULY, 1881. The visitation at the Royal Observatory, Greenwich.

The Astronomer Royal in his report states that the American extension of longitude carried on under Lt. Comdr. Green, U. S. N., to which reference was made in the last report, will be most useful for the transit of Venus in 1882.

BUREAU OF EDUCATION.

Circular of Information, No. 6, 1880.

From this, a report on the teaching of Chemistry and Physics in the United States, the following extract is made (pp. 87 and 88):

"Since the Naval Academy is an institution different in kind and in special purpose from any of the other schools which we have to consider, a few words just here may not be out of place concerning the usefulness of science to a naval officer. It was not until years after the establishment of the Academy that physics and chemistry were given much weight in the course of study; and although, through force of circumstances, these branches have brought themselves more and more into prominence, there is yet in the minds of many naval officers only a vague idea of their value, and in some cases even a strenuous opposition to their growth in the academic curriculum. These studies are also opposed by those who regard a man's attainments in mathematics as a true measure of his ability, and who consequently look with contempt upon natural science except when it admits of mathematical discussion. It would be easy to point out the fallacies which underlie these sources of opposition, but such an argument is outside the scope of this report. The purpose of the writer is, not to show the relative value of the studies in question with reference to other studies, but their actual utility to the naval officer.

"The commanding officer of a ship is the ruler of a community, the head of a household. Within the narrow walls of a vessel inclosing hundreds of men are contained all their food and water, all their clothing, and all the materials for the pursuit of their various callings. There the men eat and there they throw off their effete material, and the care of all depends upon the commander. He is responsible for the purity of their food and for the hygienic condition of their surroundings. Surely a familiarity with the results of modern scientific investigations cannot but be useful to him. Again, the instruments upon which he depends for his safety, the sextant, the compass, the chronometer, and the barometer, are purely physical instruments, and a knowledge of the principles which their construction and use involve must be of as great value to him as an acquaintance with the way in which the formulas and the tables that he employs in his calculations were deduced. If we consider the armament, we find that here again the progress of modern science is such that the intelligent officer must become familiar with her results. Improvements in the gun and in the torpedo can only be effected rationally by the scientific officer, and without a knowledge of chemical science the new explosives cannot be comprehended, or even used without great danger.

"Furthermore, naval officers are at different times on duty in the Naval Observatory, as observers, rating chronometers or correcting compasses. At the

Hydrographic office they compile and compare thermometrical, barometrical, and hydrometrical observations, and observations on the winds, tides, and currents. They take the records of soundings and of surveys, and make charts of the ocean, bottom and surface, for the whole world. They are attached to the Coast Survey, doing all the varieties of work in which the survey is engaged; to the Bureau of Steam Engineering, designing the machinery for our ships; to gun foundries, superintending the construction of ordnance; to gunpowder mills, supervising the manufacture of powder. They are detailed in boards to inspect food, fuel, materials, and clothing. In every one of these occupations a knowledge of either physical or chemical science is advantageous, and in some cases absolutely necessary."

COULBURN'S UNITED SERVICE MAGAZINE.

July, 1881. Some vessels ancient and modern. The training system in the German navy (translation.)

September. The navy.

EDINBURGH REVIEW.

July, 1881. The storage of electricity.

FICTION.

Vol. 1, No. 10. The end of New York.

A clever little story upon the *Battle of Dorking* type, by an ex-naval officer whose identity is indicated by his assumed name—Bentley Parker. A Spanish consul landing in New York is arrested, through a mistaken identification, for extradition to Chile. After the usual interchange of diplomatic notes, war follows. Two engagements at sea take place; then a Spanish fleet of armored vessels appears off Sandy Hook, forces an entrance into New York harbor, and levies an indemnity of fifty millions dollars upon the cities of New York, New Jersey, and Brooklyn. Before the money is paid, by the aid of a storm and of the Chilian armored fleet of three vessels, the Spanish fleet is destroyed and New York relieved.

The article has had a wide circulation throughout the country, and is likely to do good in calling popular attention to the weak state in which our coast and naval defences have fallen.

FRANKLIN INSTITUTE JOURNAL.

July, August, 1881. Experiments with screw propellers.

September. Condensing vs. non-condensing engines.

INSTITUTION OF MECHANICAL ENGINEERS.

Transactions, April, 1881. On riveting, with special reference to ship-work.

MILITARY SERVICE INSTITUTION OF THE U. S.

Journal, Vol. II, No. 7.

The Pratt Range Finder. This ingenious instrument, weighing about one ounce, was invented by Lieutenant Sedgwick Pratt, U. S. A., for measuring distances. It consists of an upper and lower plate, triangular in shape, parallel to each other, the apexes of the plates being connected by a vertical post, and the bases by a light framework called the back, in which there is an opening for the line of sight to pass through. Above and below the aperture in the back is a mirror, and hinged to one side of the back is a second mirror fixed at an angle of 45° with the first one and extending down from the upper plate to the aperture. To the other side of the back is hinged a third mirror, fixed at an angle of 43° 34′ 7½″ with the first one, and extending up from the lower plate to the aperture. These two mirrors converge at the vertical post connecting the apexes of the upper and lower plates, and are adjusted by means of screws in the post.

To measure a distance between two points A and B, stand at A and observe B through the opening in the back, and observe the reflected image made by

the upper mirror and the one in the back, fixed at an angle of 45° to each other, then move with the instrument in a direction perpendicular to a line drawn between A and B, to a point C where the point A, seen by means of the lower mirror and the one in the back, fixed at an angle of 43° 34′ 7½″ to each other, coincides with the point B as seen through the aperture. The angle BCA=87° 8′ 15″ and the angle ABC=2° 51′ 45″ and AC, its tangent, will be one-twentieth its radius; hence, if we measure AC and multiply by twenty, the product will give us the distance between A and B. This little instrument has given excellent results in practice.

The Marvin Shell Extractor, a device for removing a headless shell from a breech-loading small arm. It consists of a slotted steel tube, flanged at one end, and provided with an expansion pin for spreading the tube after insertion in the shell. The extractor is inserted in the shell and is expanded by closing the breech of the gun, so that when the breech is again opened the shell is withdrawn. The following points are claimed in its favor: it is light, simple, strong, certain of action, and can be used by the rawest recruit.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

Nos. IV and V, 1881. Experiments for improving the construction and use of steering compasses. Resumé of German and foreign patents. Demonstration of the law of relative velocities due to the form of the wave arising from the resistance of the ship. The war in South America. An experiment for determining the local mean time at sea without the use of goniometry, by observations on the rising or setting of stars. A method of signaling by which a ship's course is accurately marked. The electric light for coast lighting. Austro-Hungarian navigation in foreign countries. Notice of the English, French and Italian ships in service. Budget of the Russian navy for 1881. The use of steel in the construction of merchant ships. New order concerning uniform regulations for signaling, to prevent accidents at sea. The outline of the Atlantic ocean. The classification of iron and steel. Statistics of ships lost in 1880. Directions for preventing collisions at sea.

Nos. VI and VII. Improvised torpedoes and defences to ward off torpedo assaults. Opinions upon the education of machinists-in-charge for the imperial navy. Biographical sketch of Lt. Carl Weyprecht. Method of arranging two dynamo-electric machines for getting a combined current. Continuation of the study of the chronometer. A system for testing the speed of ships. The Russian torpedo boat Batum. Ships of the German navy in service. Budget for the Swedish navy for 1881. Krupp's 26 cm. cannon of 26 caliber's length. The English navy. Budget of the French navy for 1882. The Corinthian canal. Scientific expedition to Lapland. Third international geographical congress. The classification of iron and steel.

Nos. VIII and IX. The armored coast defences of England. Manufacture of sail cloth. New armored ship for China. Torpedo boat for China. New gunboats for China. Trial of the speed of the German armored corvette Württemberg. The English torpedo ram Polyphemus. New classification of the vessels of the French navy. Naval brass. Electric lighting on ships. Dr. Fleischer's hydromotor ship. Physical researches in the Adriatic and Sicilian seas during the summer of 1880—[a full and valuable paper].

MITTHEILUNGEN UEBER GEGENSTANDE DES ARTILLERIE UND GENIE-WESENS.

No. VII, 1881. Upon the material for the construction of magazines and laboratories for explosives.

Nos. VIII and IX. Upon Boutney's and Foucher's method for the commercial manufacture of dynamite.

NORTH AMERICAN REVIEW.

Aug. 1881. A militia for the sea, by Mr. John Roach.

The author proposes "to show our present naval condition, the costly consequences of naval weakness in the past, the urgent necessity to provide naval

protection in the future, and to suggest a plan to provide this protection in the most economical and effective way,—a way at once profitable to the government and promotive of our commerce." After discussing the various points mentioned, Mr. Roach submits as his plan, "the construction of one hundred fast iron screw steamships, to be divided into five classes. All to be engaged in the foreign trade." The five classes to be composed of vessels of from four thousand to two thousand five hundred tons, with a speed of sixteen knots for the largest class and of fifteen knots for the others. The government is supposed to appropriate three to five million dollars yearly as subsidies to the lines employing these steamers for carrying the mails and opening new markets to our productions. Mr. Roach knows one man "from whom one quarter of the amount needed to construct the whole fleet could be procured at once on the following basis: The government to advertise . . . for the building of such steamers, to run on such service for a term of ten years, these ships to conform in speed and tonnage to those above classified, to be built on plans approved by the government, limiting the mail service to a certain amount per mile according to the speed and tonnage, to be given to the lowest bidder." A plating of steel armor nine inches thick and nine feet deep is kept ready, and in case of war the vessels, in thirty days, can be converted into swift armored cruisers at a small cost. "One of the four thousand ton class would require a crew of three hundred and fifty men," and "would carry independent of small arms, torpedoes, ammunition, and provisions for her crew, three thousand tons of coal, which would keep her at sea four months," without the aid of sails.

In conclusion, Mr. Roach says: "If anybody has a better plan than mine to propose, let him propose it. Something ought to be done for our navy at once. The present plan is intended to build up a navy and revive our carrying trade at the same time. Such a fleet might well be named the militia of the sea."

REVISTA GENERAL DE MARINA.

July, 1881. Notes on electricity (continued). Compasses and their adjustment in iron ships (translation). Resumé of the accidents in Russia in handling torpedoes (translation). Reckoning of time and the choice of a prime meridian. The Inflexible (translation). The corvette Aragon. Chain fastenings for securing a battery.

August. Shell rooms. Notes on Japan. Studies of spectrum analysis. Glances at the war between Chili and Peru (translation). The German navy. Dictionary of the English armored vessels (translation).

September. The interior of the earth. Steam generators. The corvette Aragon.

REVUE DES DEUX MONDES.

July 15, 1881. The war in the Pacific—the causes, the engagements at Iquique and Point Angamos, and the capture of the Huascar.

September 1. New Zealand and the small islands adjacent. The voyages and reports of Captains Dumont d'Urville, Laplace, du Petit-Thouars, Fitzroy, Wilkes, and James Ross.

REVUE MARITIME ET COLONIALE.

April, 1881. The sea fisheries. The value of K in the range formula. General table of contemporary naval history. With this paper, Captain Chabaud-Arnault brings his extremely valuable record of the principal naval events of recent years to an end. It includes desultory naval operations in Mexico, in Japan, in the war between Germany and Denmark, between Peru and Chile, between Austria and Italy, between Paraguay and Brazil, and the French expedition to Corea. A general view of the navies of the maritime powers in 1868 is then given. The navy of the United States is classed as among those of second importance, with those of Spain, Holland, Sweden, and Turkey. The author then gives the inferences he draws in regard to the defences of coasts, the construction and armament of ships, torpedoes, the types of armored vessels, naval artillery, and unarmored cruisers. From the actions in the recent war in the United States,

the author concludes that land batteries, even when well constructed and fortified, are powerless, unaided by torpedoes and light draft rams, to prevent the forcing of a passage by steam fleets. He shows that it was during this war that the whole system of naval warfare was revolutionized by the introduction of rams, armored turrets, and torpedoes, and in conclusion discusses the changes brought about in naval tactics by the introduction of these novel engines of destruction.

The tactics of ramming. English colonies, Victoria. Dictionary of the Russian armored vessels. Marine steam engines.

MAY. Lunar distances. Martinique. Naval tactics. The royal naval academy from 1775–77. English colonies, South Australia. Dictionary of the Turkish armored vessels.

JUNE. Dictionary of the Austrian armored vessels. Admiral Duperré and the Algerian expedition. Martinique. Compensation of the compass by means of soft iron. English colonies, West Australia. Research into the effect of the curvature of screws.

ROYAL GEOGRAPHICAL SOCIETY. PROCEEDINGS.

JULY, 1881. The annual address on the progress of geography.

In connection with Arctic adventure, the president, Lord Aberdare, mentions the journey of Lieutenant Schwatka, U. S. A., also the voyage of the Corwin in 1880 in search of the Jeannette. He adds that the Helen and Mary, under command of Lieutenant R. M. Berry, U. S. N., is to start on a voyage for the same purpose, and says: "I sincerely trust that before the close of the coming season we shall receive news of the Jeannette's safety, and that Lieutenant De Long and his gallant companions have been restored to their friends, after having added largely to our geographical knowledge."

ROYAL UNITED SERVICE INSTITUTION JOURNAL, No. CX.

The pumping arrangements of modern war ships. Study of the tactics of naval blockade as affected by modern weapons. In this paper, Captain Samuel Long, R. N., after giving a short historical retrospect, discusses naval blockades, "instituted against fortified commercial ports to stop commerce with the enemy and prevent the issue of privateers or war ships." He finds that "the proceedings of the federal navy on the coast of North America during the war of 1861–5 furnish the most conspicuous example of this kind." In conclusion he says: "To sum up, then, it appears that where it is required to institute a blockade, the best mode to render it efficient is to seize an island or point commanding the channel, and lay down electro-contact mines. Where this is impracticable, but the channel narrow and extending far from land, to lay down mines resting on a floating base. Where neither is possible, organize a suitable squadron, with numbers of light swift vessels, resting on a favorable base, and after practice and with a fair proportion of time off duty, it is probable that a fairly efficient blockade would be maintained, and that squadrons would find it more difficult to escape unperceived than formerly." Tables appended give the coal consumption, etc., of torpedo boats, and the probable coal consumption of a blockading squadron.

Naval tactics. Vice Admiral Dowell, C. B., furnishes a paper on this subject, in which he treats of naval tactics in connection with squadrons composed of ironclad ships. In doing this he considers—(*a*) *The Composition of the Squadron.* He advocates the maintenance of three squadrons of eight or ten ironclad ships each. Every squadron should have attached to it two fast lookout vessels, and two fast unarmored frigates or corvettes, taking no active part in any engagement, but prepared to assist the crews of any disabled or sinking ship of friend or enemy. The etiquette of the present day should be, that vessels will not be molested in such work unless they in any way join in the action. Battles will in future be fought at such a speed that any vessel disabled will soon be left behind, and there would therefore be no temptation to disturb the frigates in their endeavors to save life. The ships should be painted alike, with a dis-

tinctive mark, such as a white streak, to distinguish them from the enemy. Also the mastheads of all ships should be painted alike, with a distinctive mark in addition to the vane now ordered to be carried. A water-line, visible as the smoke lifted, would be an advantage, black and white being the best colors for this purpose. (*b*) *The Armament of the Squadron.* Of the three weapons, the ram, the gun, and the torpedo, the two former are placed nearly on a par, whilst the latter is considered an an auxiliary only. The gun and ram are placed so much on an equality, because of the range of the former and its capability of being trained. An enemy cannot escape a well directed broadside, whereas it is possible by the use of the helm, by increasing or decreasing the speed, to avoid the ram, though the latter when it takes effect is the deadliest weapon of the two. In the use of the ram the endeavor should be to gain sufficient room abeam to turn with the helm eased, and a distance of one and a half cables is suggested for this purpose. Though guns of the present day have a range of several miles, their effectiveness is limited by the armor they have to pierce and the angle at which they must strike. The author therefore recommends that fire should be reserved, except on special occasions, until the distance is less than one thousand yards, and the bearing as nearly as possible at right angles to or on a line with the adversary's keel. In case of an enemy endeavoring to escape, bow fire would be of use at greater distances, to damage if possible her steering gear. In regard to the method of discharging guns, electric firing should be used at all times when a broadside is required to be delivered at ships rapidly passing, or when the ship herself is rapidly turning. Under other circumstances it would be an error for the officer at the director to assume the functions of officers in the battery and the captains of the guns. The use of the Whitehead torpedo should be limited to four hundred yards, and with respect to spar torpedoes the author considers them a very doubtful weapon for ironclad ships. (*c*) *The Organization of a Squadron.* In organizing a squadron of mixed broadside and turret ironclads, it would be desirable to place the ships of each class in separate divisions, though if unevenly divided there can be but little reason why they should not work in the same division or group. Ships throwing the heaviest weight of metal should be leaders of divisions, subdivisions, and groups, even though these ships are commanded by junior captains. The author speaks strongly in favor of the group system adopted in the English service, and of the imperative necessity of officers possessing a thorough and practical knowledge of the signal-book. The squadron should steam in regular order, except at night, in crowded waters, or in heavy weather. The efficiency of a squadron depends upon the ships being in station. With the ships in station the squadron is a machine which can be moved at once in any direction with perfect safety; but with ships out of station it is an irregular mass, which an admiral would be unable to move for fear of accidents. From seven to eight knots is considered the speed most advantageous for engaging an enemy. This allows a sufficient margin for increasing or decreasing speed to effect or avoid a ram. Ships should turn the same way to ram, and when the question is open, an advantage would be gained by attacking to leeward, in order to avoid the smoke that hangs so long on the lee side. (*d*) *The most effective Method of bringing the Squadron into Action.* The author proposes four plans of attack, viz., for an enemy in single column; in line; column of pelotons (equilateral groups); and in pelotons abreast. Case I. A's squadron of six ships sights an enemy's squadron B, also of six ships, at a distance of four miles, in single column, steering a nearly opposite course. A's admiral decides to attack in columns of groups in quarter line, attacking B on starboard or port side as he may think most advantageous. Case II. The enemy's squadron is observed to be in line, A's admiral forms groups abreast, leaders four cables apart. Case III. The enemy's squadron appears in column of pelotons. A's admiral decides to attack on B's starboard side, in column of groups in quarter line, as in case I. Case IV. The enemy is found to be in pelotons abreast (line), steering toward A's squadron. A's squadron in group formation abreast, steers so that its leaders of groups shall pass half a cable abeam of B's right flank ships. The author calls attention to the immense importance of exercising squadrons.

To make a squadron thoroughly efficient, the admiral must have confidence in his captains, the captains in each other, and the lieutenants in their brother officers, and no portion of the country's money is put to better interest than that spent in training naval officers and men to fight its ironclad squadrons.

NO. CXI. The further development of the Thornycroft torpedo vessels.

Mr. Jno. Donaldson, of Messrs. Thornycroft & Co., gives an account of the progress made in the improvement of the torpedo boats up to date. There seems to be no radical change or marked improvement in their construction or equipment. The larger class of boats, which are intended to act independently, and which are expected to be able to keep the sea under ordinary circumstances, have been gradually increased in size, while the smaller class, which have to be hoisted in and carried by vessels, remain of about the same dimensions. Several improvements in the details of the construction of the boats are noted, among them an attachment to the boiler by which the water may be heated by steam conveyed by a hose from the vessel's boilers. Steam is conveyed in like manner to a fan in the boat, accelerating the fires by an artificial draft. This arrangement was tried in competition with the Herreshoff boiler, but the latter was found to be able to get up steam rather more quickly. Its success however was considered sufficient to warrant its adoption in all boats then in process of construction. The turbine wheel is being tried as a hydraulic propeller, but the results with reference to speed are not given. The Herreshoff boiler is also being tried in a few of the new boats. An apparatus, patented by Mr. Thornycroft, is being applied to the boilers of the locomotive type for preventing accidents to stokers, in the event of the bursting of a tube or other sudden leakage of steam into the interior of the boiler. The larger boats, in addition to the Whitehead torpedo, which may be considered as their proper armament, are supplied with a spar torpedo and a machine gun. They are also constructed with a ram bow, to give them additional means of attacking, and defending themselves from other boats.

A NEW NAVIGATIONAL SOUNDING MACHINE AND DEPTH-GAUGE.

In his opening remarks the author, Sir Wm. Thomson, LL. D., F. R. S., says: "The objects sought to be attained by this new instrument are twofold: first, to protect the wire from rust more completely and more conveniently; and secondly, to supercede the necessity for using the chemically-prepared tubes, one of which had to be used every time a cast was taken." Both machines, the old and the new, are intended for the same purpose, *i. e.* to obtain soundings to depths not greatly exceeding one hundred fathoms, without stopping or diminishing the speed of the vessel. The points in common may be stated as follows: A reel containing a coil of pianoforte wire is mounted on standards, and has a circumferential V-groove for receiving a "friction-rope" to operate as a controlling brake when wire is being paid out, the amount of frictional resistance thus applied being correctly adjusted by means of a weight suspended from the free end of the rope. A register shows the number of revolutions made by the reel, but the true depth is obtained from a pressure-gauge sent down at each cast. The essential points of difference are as follows: The necessity for removing the reel from its bearings in order to place it in the tank of lime-water used as a preservative of the wire has been obviated. The new reel and standards are mounted upon the tank when in use, and it is only the work of a few seconds to dip the whole machine bodily into the tank between casts. Although both the old and the new gauges are dependent for their indications on the compression of a volume of air by hydrostatic pressure, they differ widely in construction. The old gauge consisted of a plain glass tube closed at one end and coated inside with chromate of silver. It was inclosed in a metal case and lowered with the open end downwards. The change in the appearance of the chemical coating showed the height to which the water had penetrated the tube, and the application to the tube of a graduated metal scale, made for the purpose, gave the number of fathoms of depth reached by the gauge.

In the new device, which the inventor styles the "*Triple Depth Gauge*," he has followed the general features of the Ericsson gauge—patented in 1837—in having two communicating chambers, one being used as a receiver and the other as a reservoir ; but improvements have been made to insure that the indications of the instrument shall not be vitiated by water entering or leaving the reservoir during the violent usage inseparable from an ascent made while the ship has headway. To prevent the egress of water from the reservoir he uses a guard tube projecting into the latter in a manner similar to that employed in the non-spilling ink-bottle. This device proves entirely efficacious so long as the reservoir is not more than half full. He combines in a single case or holder a set of three gauges which differ from each other only in the relative capacity which the receivers bear to their respective reservoirs. Each gauge is applicable to different depths, but their several capacities are so adjusted relatively to each other that the range of the instrument is continuous from eleven fathoms to one hundred and twenty-six and one-half fathoms. In the first gauge of the series the overflow from the receiver into the reservoir takes place at eleven fathoms; and at twenty-seven and one-half fathoms when that reservoir, being half full, is no longer to be trusted, the reservoir of the second gauge begins to receive an overflow, and so on. Over the open end of each *receiver* a piece of fine cotton cloth is tied. The wet cloth with light pressure is air-tight although permeable by water, hence during the ascent every drop of water is expelled from the *receiver* by the pressure of the expanding air before any air escapes, and the gauges come to the surface with the receivers perfectly drained of water.

SOCIÉTÉ DES INGÉNIEURS CIVILS. MÉMOIRES.

APRIL, 1881. The ports of Antwerp and Toulon.

JULY. Report of M. Vincent on celluloid. Celluloid is a complex product formed by mixing nitro-cellulose with camphor. It is hard, elastic, transparent, and capable of taking a high polish. Its density is 1.53. We can, by adding to it various coloring matters in a pulverulent condition, give to it the appearance of ivory, ebony, coral, etc. It was discovered in 1869 by Mr. Hyatt, of Newark, New Jersey. It softens at about 80° C., and can then be readily moulded. It begins to decompose slowly at about 130° C., and very rapidly at higher temperatures. It can even be partially detonated between 130° and 140° C. We ought then to protect it from any considerable elevation of temperature and store it only in small quantities. The pyroxiline is made from cigarette paper of good quality by immersing it for twelve or fifteen minutes in a mixture of five parts of sulphuric acid of 66° and two parts of nitric acid of 42° B., at a temperature of 35° C. It is then washed, triturated to a paste and bleached with permanganate of potash, and then treated with sulphurous acid to remove the oxide of manganese, and finally washed. This substance mixed with camphor forms celluloid.

The use of dynamite in the destruction of bridges, by M. Brunet. The amount of dynamite to be employed depends upon whether we are to use it against pier or metal girders. In the first case where it is placed in bore holes, M. Brunet calculates the amount of dynamite to be used by formula (1), page 122, vol. VII, U. S. Naval Institute Proceedings. For the second case, where the dynamite is a cartridge to be placed in contact with the girder, he uses the formula $L=d^2$, given on page 140, vol. VII, Proc. U. S. Naval Institute. Several instances of the successful use of dynamite in the quantities thus estimated are cited.

BOOKS RECEIVED.

American Geographical Society. Bulletin No. 6 of 1879, and No. 5 of 1880.

American Institute of Mining Engineers. Papers read at the Philadelphia and Virginia meetings (26).

American Metrological Society. Proceedings, Vols. I and II. List of members.

American Society Civil Engineers. Transactions, June, July, August, 1881.

Ericsson's Submarine Torpedo System.

Fiction. Vol. I, No. 10.

Franklin Institute, Journal, July, August, 1881.

Institution of Mechanical Engineers, April, 1881.

Military Service Institution of the U. S. Journal, Nos. 6 and 7.

Mittheilungen a. d. Gebiete d. Seewesens, Vol. IX., Nos. 4 and 5, 6 and 7, 8 and 9 (3).

Moniteur de la Flotte, No. 43, 23d year.

North American Review, August, 1881; from Mr. C. P. Hewes.

Réunion des Officiers, Bulletin No. 44, 11th year.

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Royal United Service Institution Journal, Nos. CX and CXI.

Société d. Ingénieurs Civils, Mémoires, April to August, 1881 (5).

Wörterbuch der Marine. Parts 1 to 9. By P. E. Dabovich.

Annual Report of the Light House Board, 1880.
Circular—Consumption of Oil.
Courtnenay's Automatic Signal Buoy.
Illumination and Beaconage of the Coasts of France.
Instructions to Light-keepers, 1881.
The U. S. Light House Establishment.

From Commander George Dewey, U. S. N., Naval Secretary Light House Board.

The following members have joined since the publication of the last catalogue.

Members. (24)

Ayers, J. G., Surg., Navy Department.
Blish, J. B., Midn., Constitution.
Briggs, J. B., Lieut., Naval Academy.
Caldwell, W. M., Esq., No. 1202 18th St., Washington, D. C.
Dougherty, J. A., Midn., Constitution.
Garrett, L. M., Midn., Constitution.
Garrett, L. O., Midn., Constitution.
Greer, J. A., Capt., Annapolis, Md.
Harlow, C. H., Midn., New Hampshire.
Kennedy, C. W., Lt. Comdr., Naval Academy.
Lawrence, F. W., Esq., Brookline, Mass.
Lewis, C. I., Asst. Paym., Frankfort, Ky.
Manney, H. N., Lieut., Naval Academy.
Marsh, C. C., Midn., Constitution.
Mattice, A. M., P. A. Engnr., Naval Academy.
Miner, R. H., Midn., Constitution.
Parker, James, Esq., No. 37 William St., New York.
Ramsay, F. M., Capt., Naval Academy.
Roller, J. E., Master, Saratoga.
Ryan, J. W., Midn., Saratoga.
Shipley, J. H., Midn., Saratoga.
Wilkes, John, Esq., Charlotte, N. C.
Wilson, Byron, Comdr., No. 208 Spruce St., Philadelphia, Pa.
Winterhalter, A. G., Ens., Constitution.

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Associate Members.

Simpson, J. M., Capt., Chilian Navy, Valparaiso.
Wilson, A. E., Lieut., Chilian Navy, Valparaiso.

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. VII. No. 4. 1882. Whole No. 18.

NAVAL INSTITUTE, ANNAPOLIS, MD.

JANUARY 28, 1881.

LIEUT.-COMMANDER P. F. HARRINGTON, U. S. N., in the Chair.

THE COEFFICIENT OF SAFETY IN NAVIGATION.

(*Concluded.*)*

By PROF. W. A. ROGERS, of CAMBRIDGE (U. S.) OBSERVATORY.

I now enter upon the consideration of the fourth topic. As has been already stated, the British government in 1714 offered a reward of £20,000 to any one who should discover the longitude at sea within thirty miles.

Two methods were proposed for the solution of the problem.

Morin proposed what is now substantially the lunar method; and Maskelyne devoted all his energies to the solution of the problem by observing astronomical phenomena, such as the eclipses of Jupiter's satellites. Maskelyne made a trial of this method during a voyage to Barbadoes, with an apparatus suspended from the rigging of a ship, called Irwin's marine chair. But the attempt was not successful, owing to errors occasioned by the motion of the ship.

On the other hand, mechanicians devoted every energy to the mechanical solution. Huygens had, as early as 1665, in a voyage to the coast of Guinea, made the trial of the method by watches, without success. Trial of this method was now renewed with watches made

* See p. 205 *et seq.*, No. 3, Vol. VII, Proceedings Naval Institute.

by this maker, but it was soon found that the method would be of little value till some contrivance was devised for correcting errors produced by the variation of the temperature. At last Harrison, by the very perfection of his workmanship, produced a chronometer with which a trial of the coveted prize was made in a voyage to Jamaica. As the longitude of the island differed from that shown by his chronometer by only ten and three-quarter miles, he claimed the reward, which, after a successful second trial, was awarded to him.

We have, then, two essentially different methods for the determination of the longitude at sea:

(*a*) By lunar distances, occultations, and eclipses of Jupiter's satellites, &c.

(*b*) By chronometers, assuming a constant rate throughout the entire voyage.

The latter method has for a long time been regarded as far more reliable than the former. Let us examine into the grounds of this opinion. We are, at the outset, met with the difficulty that in observations at sea we have no means of comparison with the truth. It is not sufficient to say that several observations agree with each other. Agreement *inter se* may be quite a different thing from agreement with the truth. We are obliged to have recourse to observations made on land, and then find, if possible, some means of comparing the value of these with those made at sea.

Even in the determination of the positions of fixed observatories, in which appliances for the utmost refinement are at hand, the values derived often vary widely from the truth. As late as 1755, a century after the establishment of the observatory at Greenwich, the difference of longitude between that station and the Paris observatory was assumed to be 9m. 16s. Gen. Roy, in the progress of the trigonometrical survey of England, obtained the value 9m. 18.8s. In 1796 9m. 20s. was assumed to be the correct value. In 1830 it was found to be 9m. 21.5s. from one thousand transits of moon and stars, while the actual difference, as determined by the telegraphic method, was found to be 9m. 20.6s. We have here a variation of 5.5s., or one and one-quarter miles.

The range of the earlier determinations of the difference between the longitude of Greenwich and Brussels is ten miles. A thorough discussion from moon culminations in 1836 gave a result which differs from that since found by the telegraphic method over 1s. To indicate the magnitude of the errors of longitude of the old State House,

Boston, from transits of planets over the sun and from eclipses, I give the results of the several determinations by Dr. Bowditch:

	State House from Greenwich. h. m. s.	Greenwich from Harvard Col'ge. h. m. s.	Deviation f'm truth. s.
From transit of Mercury....1743	4 44 19.2	4 44 31.6	— 0.7
Eclipse of the sun..........1766	17.5	29.9	+ 1.0
From transit of Venus 1769	18.0	30.4	+ 0.5
Eclipse of the sun..........1778	14.9	27.3	+ 3.6
" " " 1791	18.0	30.4	+ 0.5
" " " 1806	11.8	24.2	+ 6.7

We have here an absolute error of 2.2s., or more than one-half a mile, with a range of 10.3s. In passing, I may say that these results are a remarkable approximation to the true value, but they were deduced by one of the greatest and most practical mathematicians then living. They are, however, hardly comparable with any single observation, either on land or sea. During the time it would take an ordinary computer to "work up" these observations, a fast-sailing ship would be well on her journey around the world.

Perhaps the best illustration of the uncertainty resting upon the early determinations of longitude is furnished by the various values of the longitude of Washington, which have been given.

In 1822 Lambert found for the longitude of the Capitol:

		h.	m.	s.
Occultations in 1793......	$\lambda =$	5	7	5.2
" " 1804......			7	37.7
Eclipse in 1811............			8	21.8
" " 1813............			7	43.5
Value adopted.......		5	7	42.0

Elliott in the same year found $\lambda =$ 5h. 8m. 7.2s., but his value was rejected from the mean given above, on account of its supposed discordance. We have here a range of over nineteen miles, and the final value is nearly six miles in error.

Even in the determination of the longitude of the present observatory there is comparatively a wide range between the different results.

Adopting $\lambda =$ 5h. 8m. 12.1s., we have:

		Value Found.	Correction.
		h. m. s.	s.
Bond Chronometer expedition..........1849-50		5 8 12.0	+ 0.1
" " " 1851		12.3	— 0.2
" " " 1855		13.4	— 1.3
From moon culminations	Loomis.....	5 8 7.4	+ 4.7
	Gillis	10.0	+ 2.1
	Bache	9.9	+ 2.2
	Newcomb..1860	11.6	+ 0.5
	Newcomb..1862	9.8	+ 2.3
Eclipses.................	Bache...........	11.1	+ 1.0
	Pierce..........	11.6	+ 0.5
Occultation of Pleiades....	Pierce......	11.4	+ 0.7

We have here a range of 6s., or one and one-half miles, while the mean is in error 1.3s.

Two hundred and six moon culminations gave a longitude for San Francisco which has since been found to be 4s. in error.

The telegraphic determination of the longitude of Lisbon, by Lt. Comdr. F. M. Green, U. S. N., giving a result 8s. different from the accepted value, is the most recent instance of an erroneous value.

These examples are sufficient to show that it is no easy task to determine accurately the geographical position of a point on the earth's surface, even under the most favorable conditions and with the most perfect instruments.

Resuming our investigation, we begin with moon culminations. These, though essentially the same in principle, are probably somewhat more accurate than lunars. With the exception of the Willet's Point observations of lunars, we are obliged to limit our investigation to observations of nearly the same class, viz. moon culminations. These are more accurate when the longitude depends upon observations at both of the stations to be determined, since the errors of the tables of the moon are thus for the most part eliminated.

In the case of a fixed observatory whose position has been ascertained by other and more accurate methods, we have the data for testing the accuracy of this method. Before the application of the telegraphic method of determining longitude, many observations of this class were made. I have collected and reduced the most important of these with the following results. All the observations made during a given year were grouped according to the limb of the moon observed. The number of observations for each limb and the number of years during which the observations were continued are given in the following table:

Places of observations.		1st Limb. Limiting years.	No. of observations.	2d Limb. Limiting years.	No. of observations.
Washington	.. Edinburgh...	1839–41	67	1839–41	23
Washington	.. Greenwich...	1839–42	61	1839–42	42
Washington	.. Hamburg....	1839–42	65	1839–42	12
Washington	.. Oxford	1840–41	39	1840–41	12
Washington	.. Cambridge, En.	1839–42	58	1839–42	33
Greenwich	.. Hudson......	1839–42	57	1839–40	16
Cambridge	.. Hudson......	1839–44	74	1839–42	..
Edinburgh	.. Hudson......	1838–43	86	1840–42	15
Oxford	.. Hudson......	1840–43	30	1840–	5
Hamburg	.. Hudson......	1839–44	58	1842–43	19

Omitting all details, the following results were obtained from these investigations:

Washington (Old Observatory) and Greenwich.

$$\lambda = \overset{h.}{5}\quad \overset{m.}{8}\quad \overset{s.}{2.2}$$

	Limb of moon.	No. of obs.	Mean Corr. (s.)	Extreme range in each year. (s.)
Washington .. Greenwich...............	I	60	—1.3	23.0
	II	41	—1.0	
Washington .. Greenwich via Edinburgh .	I	64	—5.1	21.8
	II	23	—0.8	
Washington .. Greenwich via Oxford....	I	32	—5.4	21.6
	II	13	—0.4	
Washington .. Greenwich via Cambridge	I	57	+0.8	19.9
	II	23	—4.6	
Washington .. Greenwich via Hamburg..	I	69	—2.6	21.6
	II	12	—2.5	

Washington and Edinburgh.

Observations at each Station.

No. observations.	Average deviation from mean for each year.	Extreme range between different years.	Coefficient.
...	2.4s.	21.8s.	3.6

Camp Riley, Boundary between United States and Mexico.

From tabular places of the moon. Comparison with mean value.

	s.	s.	
15	8.3	35.3	4.3

Hudson, Ohio.

Comparison with the mean value of series.

	No. obs.	Average deviation from mean each year.	Extreme range between different years.	Coefficient.
		s.	*s.*	
Hudson and Greenwich.	73	5.0	20.2	4.0
Hudson via Cambridge..	74	5.2	18.2	3.5
" " Edinburgh..	101	7.1	17.1	2.4
" " Oxford.....	35	7.6	13.6	1.8
" " Hamburg...	77	6.7	18.0	2.7

Brussels and Greenwich.

		s.	*s.*	
Brussels and Greenwich..	17	6.1	14.3	2.3
" via Cambridge..	15	3.2	11.7	3.7
" " Edinburgh..	17	7.0	27.6	3.9
" " Altona......	7	3.8	16.6	4.4

F. G. W. Struve in Turkey with 22-inch Transit.

Comparison with mean value.

		s.	*s.*	
Paris .. Jassy...........	11	8.2	36.9	4.5
" .. Roman.........	7	4.8	21.5	4.5
" .. Busen..........	11	7.4	29.2	4.0
" .. Kolarsch........	7	5.0	18.7	3.7
" .. Schmrscha......	8	3.5	16.2	4.6
" .. Kalafat..........	10	8.4	39.2	4.7
" .. Warna..........	18	9.7	41.5	4.3
" .. Tiflis...........	12	5.7	21.2	3.7
" .. Erzerin.........	18	7.8	25.9	3.3

WILLET'S POINT.

Comparison with transit observations.

From moon culminations.

			s.	*s.*	
	1869	18	12.6	64.4	5.1
American..	1870	17	14.5	67.5	4.7
Ephemeris.	1871	12	7.2	31.3	4.4
	1872	6	2.9	9.0	3.1
	1869	18	12.5	47.9	3.8
British	1870	18	16.6	71.0	4.3
Ephemeris.	1871	13	17.7	76.9	4.3
	1872	6	8.9	24.4	2.7

From lunar distances.

		s.	*s.*	
1870	..	34.9	67.4	1.9
1871	..	37.8	143.0	3.8
1872	..	49.5	80.9	1.6

As an illustration of the error of Mr. Main's statement that the lunar problem is completely solved, I add the details from the Willet's Point observations for 1871:

From Moon Culminations.

Date.	Corr. by British Ephemeris.	Corr. by American Ephemeris.
	s.	*s.*
January 30	— 5.2	— 17.1
September 25	— 24.2	— 9.1
" 26	+ 14.9	+ 1.6
" 27	+ 11.0	+ 1.4
" 27	+ 2.2	— 8.4
" 28	— 2.9	..
" 28	— 16.2	— 12.1
" 29	— 10.1	— 10.0
October 23	— 14.6	+ 11.9
" 27	+ 7.8	+ 0.9
" 27	+ 18.9	+ 14.2
" 28	+ 50.2	+ 0.0
" 28	+ 52.7	+ 0.1

From Lunar distances for 1870.

With Sextant.

Date.	Corr.
	s.
January 27	+ 19.1
September 3	+ 47.0
October 19	— 18.4
" 29	— 1.0
" 30	— 0.2
November 1	— 38.0
" 6	— 96.0
" 29	— 82.3

Finally, we have fortunately on this point positive and conclusive testimony from the observations of Mr. Fisher, astronomer on Capt. Parry's second voyage. He found that the mean of 2500 observations in December differed ten miles from the mean of 2500 in the following March, and that the mean of a still larger number made on both ships differed ten miles from those in March and twenty-four miles from those in December. It is the testimony of Capt. Heywood that any set of lunars may be expected to differ 6′ or 7′ from any other

set equally good, taken at a different time of the year, and this independently of accidental errors.

Collecting results, we have:

Place and Circumstances of Observation.	Average error.	Range bet. greatest and least.	Coefficient.
	s.	*s.*	
Greenwich—Edinburgh. Observations at each station, compared final result with truth	2.4	21.8	9.0
Washington—Greenwich. Observations at each station, compared final result with truth	2.1	21.6	10.3
Hudson—Greenwich, compared with mean result for each station................................	6.3	17.4	2.9
Brussels—Greenwich, compared with mean result for each station	5.0	17.6	3.5
Places in Turkey with Paris, compared with mean result at each station	6.7	27.8	4.1
Camp Riley, comp'd of mean with tabular places..	14.0	55.0	3.9
Willet's Point, compared with transit observations—			
From American Ephemeris....................	9.3	43.0	4.6
From British Ephemeris......................	14.0	55.0	3.9
Lunars compared with known positions..........	40.7	97.1	2.4

For fixed observatories, with the most perfect instruments, we must therefore expect from the lunar method of moon culminations an absolute error of 2.2s. within a range of 21.6s. as the result of any number of observations. These results correspond in a general way with an investigation made by Professor Pierce. He found the ultimate limit to be ± 0.55s. when one limb of the moon was observed. He says: "Beyond this it is impossible to go with the utmost refinement. By heaping error upon error, it may crush the influence of each separate determination, but does not diminish the relative height of the whole mass of discrepancy. But this discrepancy between the results for different limbs of the moon often amounts to 10s. in the mean determination of a year." The assumption that the ultimate limit of accuracy is as great as 1s. seems to be a very moderate widening of the limits. I find it to be 2.2s.

For fixed observatories, comparing with the mean result at any station, we must expect a relative error of 6.0s., with a range of 20.9s.

For fixed observatories, using the moon's tabular places, we must expect an error of 12.4s. with a range of 51.0s.

For lunar distances, with the sextant, on land, we must expect an error of 40.7s., with a range of 97.1s.

For single lunar observations at sea these quantities should have a coefficient at least as great as three *additional* units.

It will be noticed that the coefficient is much larger for comparisons with known values than for comparisons with the mean of a given series.

I now take up the subject of chronometers, and make a similar investigation.

The sources of error are:

(*a*) Variations of rate, arising from the action of magnetism.

The only observations under this head that I can find are those made by Mr. Fisher and by Professor Airy. Mr. Fisher made a very elaborate series of experiments, from which he found that the earth's magnetism changed the daily rate in one case 4.5s., in another 3.2s., and in another 4.1s.

Professor Airy made similar experiments and found similar results, the extreme variation on account of the influence of terrestrial magnetism being 5.8s. He found the following rates for Brockbanks, No. 425:

When the figure—

XII was north, rate = 4.64s.
" " east " = 8.70
" " south " = 9.61
" " west " = 5.75

He also found that the action of terrestrial magnetism could be eliminated by placing the chronometer on the top of a compass-box whose needle was perfectly free, provided the elevation was properly adjusted. When this adjustment was made he found for—

XII N. rate = 9.24s.
" E. " = 9.41
" S. " = 9.75
" W. " = 10.03

This corresponds with my own observations in the case of clocks. I have long noticed that the Cambridge and Boston clocks gain and lose together, due to some kind kind of a sympathetic action between the two.

(*b*) When chronometers are swung on the same support it is probable there is a sympathetic action between them similar to the results recently found with the transit of Venus clocks.

(*c*) Variation on account of change of barometric pressure. This varies between .3s. and .8s. per day for every inch of change in the barometer.

(*d*) Variation between land and sea rates. The elder Professor Bond made a full investigation of the *average* difference between the land and sea rate, and found them essentially the same. It had been previously assumed that there was an average gain of the latter over the former. But in individual cases there are, without doubt, great changes of the rate, arising mostly from careless handling in transportation to the ship.

Almost every chronometer will change its rate when its circumstances, either of rest or motion, are changed. The Boston standard clock of Messrs. Bond & Son almost invariably has a different rate on Sunday from any other day of the week. So, also, it takes a new rate when the streets are covered to any considerable depth with snow.

The jar of machinery affects the rate; hence the rate of a sailing vessel is more steady than that of a steamer.

(*e*) Variation of rate at sea, on account of change of temperature. Mr. Hartnup, of Liverpool, was the first to give the chronometer rate for different temperatures. So far as I can find he is the only one who does so now, and yet failure in this respect occasions errors of enormous magnitude. In one case which Mr. Hartnup instances, if the navigator had relied upon his *average* rate he would have been nearly sixty miles in error. This is a reform in rating chronometers which is imperatively demanded, and it is one easily accomplished.

Let us now attempt to determine the limits within which a chronometer can be depended on to give the longitude at sea. Here we are limited in a great measure to the performances of chronometers on land, inasmuch as at sea we have no means of comparison with a normal standard. The chronometer tests at the Greenwich observatory, however, afford abundant facilities for ascertaining the performance of chronometers under varying conditions of temperature. I select for discussion three series—the first from 1842 to 1852, the second from 1853 to 1862, and the third from 1863 to 1871. The quantities to be determined are the greatest difference between the rates during a given trial, which usually extended over a period of about six months, and the greatest difference of rates between one week and the next following.

The only rule followed in the selection of the chronometers chosen for these tests has been the preference given to makers who entered their chronometers the greatest number of times during the entire interval from 1842 to 1871. The method of proceeding was as follows: Hav-

ing selected for this test, *e. g.*, the chronometers of Frodsham, the quantities sought were obtained from the chronometer tests recorded in the volumes of the Greenwich observations between the years 1842 and 1871. Inasmuch as the value given for each group is a mean value, derived from the number of chronometers entered for trial between the limiting dates, I have added the greatest value for a given series. The addition of these columns is important, since the *liability* to error is as great as the greatest range of error.

The temperature at which the comparisons were made varies from about 35° to about 95° Fahrenheit. The variation of rate under nearly the same temperature will appear from the column "Greatest range in daily rate between one week and the next following."

CHRONOMETER RATES DETERMINED AT THE GREENWICH OBSERVATORY UNDER VARYING CONDITIONS OF TEMPERATURE.

Make		Frodsham.	Dent.	Reid.	Fletcher.	Lister.	Roskell.	Eiffe.	Kullberg.	Poole.	Loseby.	Cottrell.	Massey.	Appleton.	Mean by weights.
Number of Chronometers.	1842–52	9	10	7	7	6	4	7	..	9	7	7	9	7	..
	1853–62	6	10	9	2	10	5	9	3	10	1	..	..	..	..
	1863–71	9	9	8	7	8	5	4	7	5	..	..	..	..	..
		s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
Greatest range of daily rate during trial.	1842–52	3.37	2.74	3.20	3.74	4.40	5.56	2.43	..	3.21	2.07	3.70	3.39	2.90	3.40
	1853–62	2.67	3.91	3.25	3.47	3.64	6.11	5.00	3.72	3.14	3.24	..	..	..	3.83
	1863–71	2.41	1.79	2.24	3.72	2.06	2.71	3.54	1.85	2.20	..	..	..	..	2.41
Greatest range in given series.	1842–52	5.56	7.74	5.90	5.59	8.73	9.11	3.39	..	5.50	2.59	6.40	7.57	3.97	5.75
	1853–62	4.16	5.31	4.70	4.14	7.00	1260	7.50	5.60	6.77	3.24	..	..	..	6.10
	1863–71	4.40	2.91	2.87	3.49	2.41	4.24	5.60	2.63	2.77	..	..	..	..	3.48
Greatest range of daily rate bet. 1 week and the next following.	1842–52	1.87	1.54	2.06	1.56	2.50	3.24	1.67	..	1.93	0.99	2.14	1.76	1.76	1.91
	1853–62	1.79	1.93	1.73	1.34	1.79	2.70	2.29	1.33	1.63	2.17	..	..	..	1.88
	1863–71	1.20	1.01	1.07	0.87	1.16	1.81	2.47	0.83	1.13	..	..	..	..	1.19
Greatest range in given series.	1842–52	3.04	2.87	4.91	3.01	3.63	6.37	3.10	..	3.53	1.66	4.51	5.00	3.00	3.74
	1853–62	2.79	3.30	3.64	1.43	3.71	6.49	5.57	1.53	4.60	2.17	..	..	..	3.52
	1863–71	2.34	1.90	1.60	1.53	1.97	4.11	4.87	1.36	1.44	..	..	..	..	2.35

In order to exhibit still further the variations due to a change of temperature I have selected from the Greenwich reports for the years 1867–68–69–70–71 five chronometers showing the best performance, and five showing the poorest performance. The observations cover a period of four weeks, during which time the chronometers were subjected to a high temperature (about 95°), and during the period of four weeks immediately preceding, under ordinary temperature.

The headings explain the operations performed.

Year.	Class.	Maker.	Mean daily rate under ordinary temperature.	Mean daily rate under high temperature.	Var'n bet. ordinary and high temp.	Range of daily rate under ordinary temp.	Range of daily rate un. high t.
			s.	s.	s.	s.	s.
1867.	Best....	Sewill....	— 2.21	— 0.55	.66	.23	.77
		Gowland	— .85	— 1.21	.36	51	.31
		Birchall..	— 1.13	— 1.11	.02	.11	.41
		Dent	+ 1.51	+ 2.12	.61	.34	.90
		Hennesy.	— .59	— .43	.16	.99	.41
	Poorest	Lister....	+ 2.37	+ 0.57	2.94	0.39	0.43
		Shepherd	+ 1.29	+ 1.75	0.46	.78	.17
		Poole....	— 0.25	+ 3.83	4.08	.80	1.49
		Crisp.....	+ 7.96	+10.34	2.38	.79	1.63
		Johansen	+ 0.12	+ 0.43	0.31	1.30	2.04
1868.	Best ...	Birchall.	— .50	— .34	.16	0.14	.21
		Fletcher.	— 1.66	— 1.71	.05	.23	.63
		Davison.	— .62	— 1.01	.39	.34	.74
		Gowland	— 1.61	— 1.24	.37	.36	.56
		Young ..	— .73	— 1.01	.28	.19	.23
	Poorest	Sewill....	+ 1.13	+ 0.86	.27	0.19	3.29
		"	+ .05	+ 1.91	1.86	.86	.36
		Birch	— 1.16	+ 1.09	2.25	1.21	.76
		Dell......	+ 1.30	+ 3.21	1.91	1.64	.56
		Glover...	— .63	+ .84	1.47	.79	2.18
1869.	Best...	Fletcher.	— 0.52	— 0.62	.10	.30	.20
		Whiffen..	— .17	— .58	.41	.79	.04
		Dent.....	— .29	— .85	.56	.33	.04
		Kullberg	— .12	+ .34	.46	.43	.30
		"	+ .20	+ .24	.04	.36	.46
	Poorest	Carter....	+ 0.39	— .51	.90	.67	.61
		Glover...	— 7.67	— 5.02	2.65	.80	1.84
		Fletcher.	— 2.64	— 3.47	.83	.36	.36
		Cairns ...	— .51	— 2.51	2.00	.51	1.07
		Shepherd	— 3.28	+ 0.03	3.31	.44	.61
1870.	Best...	Dent.....	— .13	— .54	.41	.34	.51
		Chittend.	+ .32	— .09	.41	.31	.46
		Reid	— .76	— .34	.42	.54	.53
		Lowry ...	— .91	— 1.00	.09	.20	.60
		Kingston	+ .28	-- .48	.76	.86	.21
	Poorest	Reid	— 1.34	— .50	.84	.91	.91
		Webb....	— .05	— 2.52	2.47	.33	.94
		Whiffin..	— 2.06	+ .51	2.57	.29	1.81
		Eiffe.....	— 2.53	— .98	1.55	.71	1.71
		Gowland.	— .46	— 3.92	3.46	1.83	3.01
1871.	Best...	Frodsham	— .93	— 1.23	.30	.83	.34
		Weichert	— .54	— .68	.14	.69	.51
		Kingston	— .33	— .73	.40	.33	.41
		Dell......	— 1.12	— 1.19	.07	.54	.31
		Gowland	+ .39	+ .88	.49	.43	.56
	Poorest	Gowland	— 2.43	— 1.18	1.25	.19	1.14
		Hennesy.	— .08	— 3.09	3.11	.49	.79
		McGregor	— 3.25	+ .84	4.09	.70	.36
		Shepherd	— .28	— 3.75	3.47	.33	.74
		Reid.....	— 1.88	+ 2.59	4.47	.30	.86

Summary.

Year.	Mean diff. of daily rate between high and ordinary temperatures.	Greatest variation of daily rate.	Range of daily rate under ordinary temperature in 1 mo.	Range between different chronometers.	Range of daily rate under high temperature in 1 mo.	Range between different chronometers.
			Best.			
	s.	s.	s.	s.	s.	s.
1867	.36	.66	.44	.88	.56	.51
1868	.25	.39	.25	.22	.47	.53
1869	.32	.56	.44	.49	.21	.42
1870	.39	.76	.45	.55	.46	.39
1871	.28	.49	.56	.50	.43	.25
Means	.32	.57	.43	.53	.43	.42
			Poorest.			
1867	2.03	4.08	.80	.91	1.15	1.87
1868	1.55	2.25	.94	1.45	1.43	2.93
1869	1.94	3.39	.56	.54	.90	1.48
1870	2.18	3.46	.81	1.54	1.70	2.01
1871	3.28	4.47	.40	.51	.78	.78
Means	2.20	3.51	.70	0.97	1.19	1.81

From these tables I draw the following conclusions:

(*a*) There was a very marked and steady improvement in the construction of chronometers between 1842 and 1871. The greatest range of daily rate during the entire trial fell from 3.40s. in 1842–52 to 2.41s. in 1863–71. The greatest range of the daily rate between one week and the next following was reduced from 1.91s. in 1842–52 to 1.19s. in 1863–71. These were the palmy days of chronometer construction. I have made only a partial discussion of the trials since 1871, but the evidence is pretty conclusive that the averages are larger than for the period 1863–71.

(*b*) Under the most favorable conditions for the excellent performance of chronometers, the average change of the rate between one week and the next following exceeds 1.2s. Of course, with the newly acquired rate the accumulation of error will be proportional to the time until another change takes place.

(*c*) The *average* liability to error in the daily rate between one week and the next following is not far from 3 seconds.

(*d*) The ratio-value between the average of first-class chronometers and the average of poor ones is nearly as 1 to 7.

On the Magnitude of the Errors of Chronometers employed in Short and Regular Sea Voyages.

It will be allowed on every hand that a discussion of the actual errors of the chronometers used on the Cunard line of steamships will exhibit results considerably better than the general average. The well-known skill of the navigators in the service of this company, the perfection of every appliance, the general sameness of the conditions of each voyage, the number of chronometers employed, and the accurate rating of each chronometer at the beginning and end of each voyage by comparison with the time from fixed observatories, all conspire to give the most favorable results which can be expected from the performance of chronometers in the present state of chronometer construction. With the assistance of Mr. Aug. McConnell, I have made a discussion of the chronometer errors of the Cunard steamers sailing between Liverpool and Boston during the years 1871–1872 and 1873.

Chronometer Rates on Cunard Steamers.

Steamer.	Date of arrival at Boston.	Length of voyage.	Total error at end of Voyage. Chron. No. 1.	Chron. No. 2.	Chron. No. 3.	Mean error at end of voyage.	Range of error between Nos. 1, 2 and 3.	Mean error of daily rate.
			s.	*s.*	*s.*	*s.*	*s.*	*s.*
Palmyra.	1871, Nov. 20.	14 days.	+ 9.8	— 2.8	— 5.6	0.5	15.4	0.03
	1872, Feb. 29.	17	+ 1.7	+ 1.7	—20.4	5.7	22.1	0.33
	" April 8.	14	— 9.8	— 5.6	— 5.6	7.0	4.2	0.50
	" May 17.	16	— 9.6	—25.6	—62.4	32.5	52.8	2.03
	" June 9.	14	+ 5.6	—25.8	—21.0	13.1	29.4	0.93
	" July 24.	14	— 2.8	— 4.2	+ 5.6	0.5	9.8	0.03
	1873, March 20.	17	+ 0.0	+ 5.1	....	2.5	5.1	0.15
Olympus.	1872, April 18.	15	— 3.0	— 1.5	+ 1.5	1.0	4.5	.0.07
	" May 20.	12	+12.0	+ 6.0	+18.0	12.0	12.0	1.00
	" June 25.	13	— 5.2	— 1.3	+13.0	2.2	18.2	0.17
	" July 31.	14	+14.0	+ 0.0	+ 8.4	7.5	14.0	0.53
	" Sept. 3.	13	+ 5.2	+ 1.3	+ 1.3	2.6	3.9	0.20
	" Nov. 13.	16	+ 4.8	+ 6.4	— 3.2	2.7	9.6	0.17
	" Dec. 18.	16	+ 4.8	+ 8.0	....	6.4	3.2	0.40
	1873, Feb. 3.	21	+12.6	+ 2.1	—12.6	0.7	25.2	0.03
	" March 13.	17	+10.2	+15.3	+ 5.1	10.2	10.2	0.60
Samaria.	1871, Dec. 5.	15	+ 1.5	+27.0	....	12.7	28.5	0.85
	1872, Jan. 15.	21	— 2.1	+46.2	+ 0.0	14.7	48.3	0.70
	" Feb. 20.	15	+ 9.0	+ 24.0	+ 3.0	12.0	21.0	0.80
	" March 27.	16	+ 9.6	+14.4	+ 0.0	8.0	14.4	0.50
	" May 6.	13	+ 3.9	+13.0	+ 9.1	8.7	9.1	0.67
	" June 11.	13	— 1.3	+ 2.6	+ 1.3	0.9	3.9	0.07
	" July 16.	13	— 6.5	+ 0.0	— 1.3	2.6	6.5	0.20
	" Aug. 19.	12	— 1.2	+ 0.0	+ 3.6	0.8	4.8	0.07
	" Sept. 24.	13	— 3.9	— 1.3	— 1.3	2.2	2.6	0.17
	" Oct. 29.	13	— 2.6	+ 11.7	—19.5	3.5	31.2	0.27
	" Dec. 13.	13	+10.8	+ 5.4	+14.4	10.2	9.0	0.57
	1873, Jan. 17.	18	+10.8	+ 1.8	— 1.8	3.6	12.6	0.20
	" March 3.	14	+ 18.2	— 1.4	+ 8.4	8.4	19.6	0.60

Chronometer Rates on Cunard Steamers—Continued.

Steamer.	Date of arrival at Boston.	Length of voyage.	Total error at end of Voyage. Chron. No. 1.	Chron. No. 2.	Chron. No. 3.	Mean error at end of voyage.	Range of error between Nos. 1, 2 and 3.	Mean error of daily rate.
			s.	*s.*	*s.*	*s.*	*s.*	*s.*
PARTHIA.	1871. Nov. 27.	14 days.	+ 5.6	+ 4.2	+1.4	3.7	4.2	0.26
	1872. Feb. 5.	14	+ 9.8	+ 9.8	+ 9.8	9.8	0.0	0.70
	" March 29.	11	+ 3.3	− 3.3	+ 8.8	2.7	12.1	0.26
TRIPOLI.	1871, Dec. 19.	15	+ 6.0	− 1.5	− 1.5	1.0	7.5	0.07
	1872, Feb. 2.	18	− 1.8	+ 5.4	− 5.4	0.6	10.8	0.03
	" March 14.	16	+ 3.2	+22.4	+ 9.6	11.7	19.2	0.73
	" April 24.	14	+ 2.8	− 9.8	− 8.4	5.1	12.6	0.36
HECLA.	1872, Jan. 17.	16	+ 0.0	− 1.6	− 1.6	1.1	1.6	0.07
	" April 29.	12	−12.0	+ 3.6	+ 2.4	2.0	15.6	0.17
	" June 4.	13	− 5.2	+ 2.6	−14.3	5.6	16.9	0.43
	" July 10.	14	− 1.4	+ 2.8	+18.2	6.5	19.6	0.46
	" Aug. 13.	13	+ 2.6	+16.9	+ 1.3	6.9	15.6	0.53
	" Sept. 17.	13	−10.4	+11.7	+10.4	3.9	22.1	0.30
	" Oct. 23.	14	− 7.0	− 1.4	− 2.8	3.7	5.6	0.26
	" Dec. 5.	17	−10.2	....	−13.6	11.9	3.4	0.70
	1873, Jan. 13.	21	− 4.2	+25.2	−14.7	2.1	39.9	0.10
	" Feb. 17.	14	+ 4.2	− 7.0	+22.4	6.5	29.4	0.46
	" April 1.	15	−16.5	− 7.5	− 3.0	9.0	13.5	0.60
SIBERIA.	1871, Dec. 14.	15	+31.5	+ 4.5	+24.0	20.0	27.0	1.33
	1872, Jan. 26.	18	+ 3.6	+ 5.4	+16.2	8.4	12.6	0.47
	" March 5.	15	− 9.0	+ 1.5	+ 6.0	0.5	15.0	0.03
	" April 23.	13	− 9.1	− 3.9	+ 0.0	4.3	9.1	0.33
	" May 28.	13	+ 2.6	+ 0.0	+ 7.8	3.5	7.8	0.27
	" July 3.	14	− 4.2	+12.6	+ 4.2	4.2	16.8	0.30
	" Aug. 5.	12	+ 6.0	+ 4.8	+ 3.6	4.8	2.4	0.40
	" Sept. 10.	13	− 1.3	+ 7.8	+ 3.9	3.5	9.1	0.27
	" Oct. 16.	14	+ 5.6	+11.2	+ 9.8	8.9	5.6	0.63
	" Nov. 20.	14	− 1.4	+ 9.8	−36.4	9.3	46.2	0.63
	" Dec. 31.	22	+ 2.2	....	+ 4.4	3.3	2.2	0.15
	1873, Feb. 7.	18	+ 9.0	+ 0.0	− 5.4	1.2	14.4	0.07
	" April 14.	12	+ 1.2	− 9.6	− 3.6	4.0	10.8	0.33
BATAVIA.	1872, Jan. 3.	16	+ 4.8	+ 3.2	+ 3.2	3.7	1.6	0.23
	" Feb. 15.	17	+18.7	+ 3.4	+ 0.0	7.4	18.7	0.43
	" March 20.	16	− 1.6	− 9.6	− 6.4	5.9	8.0	0.37
	" Nov. 25.	14	− 1.4	+22.4	+ 8.4	9.8	23.8	0.70
	1873, Jan. 20.	14	− 7.0	+ 5.6	+ 8.4	2.3	15.4	0.16
	" Feb. 25.	15	− 4.5	+ 7.5	+ 4.5	2.5	12.0	0.17
	" April 7.	14	− 2.8	+ 2.8	+ 1.4	0.5	5.6	0.03
MALTA.	1872, Aug. 29.	15	−12.0	− 4.5	−63.0	26.5	58.5	1.77
	" Sept. 30.	12	− 7.2	−34.8	−14.4	18.8	27.6	1.57
	" Nov. 7.	15	+ 3.0	+ 0.0	+ 4.5	2.5	4.5	0.17
	1873, Jan. 4.	19	−15.7	+20.9	+11.	5.5	36.6	0.29
	" Feb. 12.	16	+ 0.0	−25.6	+ 0.0	8.5	25.6	0.65
	" March 24.	14	− 7.0	−23.8	− 2.8	11.2	21.0	0.80

Average Results.

Steamer.	No. of voyages.	Av. length of voyage.	Av. Error of daily rate.	Av. error at end of of voyage.	Range between greatest and least value of series.	Range between three chronometers.	Greatest value of series.
			s.	s.	s.	s.	s.
Palmyra,	7	14.7 days.	±0.57	8.83	32.0	19.83	52.8
Olympus,	9	15.2	0.35	5.03	11.3	11.20	25.2
Samaria,	13	14.9	0.44	6.77	13	16.27	48.3
Hecla,	11	14.7	0.37	5.29	10.8	16.65	39.9
Parthia,	3	13.0	0.41	5.47	6.9	5.43	12.1
Tripoli,	4	15.8	0.30	4.60	11.1	12.52	19.2
Siberia,	13	14.9	0.40	5.84	19.5	13.77	46.2
Batavia,	7	15.2	0.30	4.59	9.3	12.16	23.8
Malta,	6	15.2	0.86	12.16	24.0	28.97	58.5
Means,	8	15.4	0.44	6.52	15.42	15.20	36.22

Chronometer Rates on Sailing Vessels.

The chronometers in this discussion were selected without regard to rates, except when the variation exceeded 2s., and the chronometers needed repairs at the end of the voyage. The materials for this part of the discussion were furnished by Mr. McConnell.

Maker.	No. of chron.	Length of voyage	Total error at end of voyage.	Maker.	No. of chron.	Length of voyage.	Total error at end of voyage.
			s.				s.
Bond & Sons.	219	182 days.	18.2	Bliss & Creighton.	818	122 days.	48.8
	239	30	0.0		1307	81	16.2
	253	84	33.6		1823	99	128.7
	163	100	30.0		878	64	64.0
	173	71	0.0		782	144	86.4
	278	44	4.4		1131	80	160.0
	232	30	15.0		1888	3	21.0
	193	178	17.8		2004	77	154.0
	275	45	4.5		1850	48	24.0
	192	74	37.0		815	82	32.8
Hutton.	265	134	13.4	Negus.	1091	51	30.6
	195	98	39.2		709	93	46.5
	492	78	7.8		1151	31	15.5
	366	147	44.1		1000	107	21.4
	218	81	5.4		1178	88	88.0
	351	141	42.3		812	181	72.4
	382	21	14.7		1154	95	28.5
	493	50	25.0		848	44	11.4
	289	20	12.0		1048	55	16.5
	160	40	12.0		829	113	33.9

Maker.	No. of chron.	Length of voyage.	Total error at end of voyage.	Maker.	No. of chron.	Length of voyage.	Total error at end of voyage.
			s.				s.
Garraud.	5175	102 days.	14.4	Frodsham.	2267	149 days.	.74.5
	2182	173	51.9		1863	47	23.5
	2552	77	61.6		2470	96	124.8
	776	0	6.7		1808	109	98.1
	2185	149	44.7		2528	135	202.1
	321	221	154.7		1945	138	41.4
	5210	56	16.8		2565	193	38.6
	2614	34	17.0		2427	56	39.2
	5117	219	87.6		2502	263	0.0
	1965	177	141.6		2690	62	37.2
Poole.	3336	14	5.6	Tobias.	1302	7	1.4
	2400	133	146.3		1472	23	13.8
	1920	189	37.8		1200	67	13.4
	1712	258	77.4		1446	52	46.8
	1299	21	31.5		1386	215	64.5
	1674	1	50.5		1673	34	6.8
	2477	49	4.9		1296	14	8.4
	3849	14	4.2		1509	229	0.0
	1628	190	19.0		1003	30	36.0
	3806	14	15.4		1216	104	104.0
Adams.	3895	294	88.2	10 other makers.	6582	76	0.0
	4225	112	156.8		2820	26	13.0
	2777	80	8.0		1965	19	5.7
	4118	75	7.5		619	78	7.8
	4328	138	165.6		654	101	50.5
	726	19	3.8		259	39	66.3
	534	84	42.0		5224	115	207.0
	766	21	4.2		927	63	37.8
	656	3	.9		902	83	24.9
	1102	2	1.0		963	113	22.6

Collecting results, we have:

Maker.	Av. length of voyage.	Av. error of daily rate.	Av. error at end of voyage.
		s.	s.
Bond & Sons,	84 days.	0.19	16.1
Bliss & Creighton,	80	0.92	73.7
Hutton,	75	0.29	21.6
Negus,	86	0.42	36.5
Berraud,	127	0.47	59.7
Frodsham,	125	0.54	67.9
Poole,	98	0.40	39.3
Tobias,	78	0.38	29.5
Adams,	83	0.58	47.8
10 other makers,	71	0.61	43.6
Means,	91	0.48	43.6

The longitude expeditions undertaken by Professor Wm. C. Bond in 1849–50, and by Professor George P. Bond in 1855, for the accur-

ate determination of the longitude between Cambridge and Greenwich, furnish the most reliable data available for a correct estimate of the degree of accuracy to be expected from the average performance of a chronometer during a short sea voyage. On these expeditions the rates of all the chronometers employed were carefully determined at each station.

In this discussion only those chronometers are selected which made three or more voyages. The longitude given by each chronometer is compared with $\lambda = 4h.\ 44m.\ 30.9s.$ The numbers given are current numbers, and not the numbers given to the chronometers by the makers. The values given under each number are the separate corrections to the assumed longitude given by the same chronometer on different voyages. The exceptional value of these determinations justifies the publication of the details.

Expedition of 1849–50.

Nos.	1	2	3	4	5	6	7	8	9	10	11
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Corrections by each Chronometer to assumed value of λ.	+0.1	+5.7	+3.0	+3.4	+26.2	+3.2	+3.6	+3.8	−0.1	+8.2	+0.1
	−13.6	+0.6	−7.1	+1.2	+2.9	+1.8	−3.3	−1.2	−1.7	+2.2	+1.4
	+7.6	+0.2	−1.1	+0.1	+0.0	+4.5	−4.4	+3.0	+1.7	−7.6	+1.9
					−16.5						
					−6.3						
					+6.8						
Means	+1.97	+2.17	−1.73	+1.57	+2.18	+3.17	−1.37	+1.87	−0.03	+0.93	+1.13

	12	13	14	15	16	17	18	19	20	21	22
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	−7.4	−5.0	+6.5	−10.9	+3.4	−0.6	−1.8	−0.3	+11.0	−12.9	+4.3
	−15.3	+1.9	−1.5	−4.4	+3.8	−1.9	−1.9	+10.5	−2.8	+15.5	+13.0
	−14.8	+1.5	−5.3	−14.5	+1.9	+10.0	+6.0	+11.7	+5.5	−10.1	+2.8
	+10.6	+12.5				−7.8	−2.2	−6.1	+0.6	+19.5	−18.4
						+8.9	+3.8	−10.9	−0.9	+0.9	−20.3
								−12.8		+2.2	+4.8
Means..............	−6.72	+2.73	−0.10	[−9.93]	+3.03	+1.72	+0.78	−1.32	+2.68	+2.52	−2.30

	23	24	25	26	27	28	29	30	31	32	33
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	+8.1	+2.9	+2.9	+7.5	+6.1	+4.3	+0.1	+0.9	+4.0	−2.3	−0.2
	+13.8	+5.9	−3.3	+16.0	−8.5	+14.6	+7.1	+10.1	+15.5	+12.5	+15.2
	−8.3	−1.4	−11.7	−10.4	+20.1	−3.9	+5.8	+5.1	−3.6	−11.4	−14.0
	−6.1	+9.0	+10.7	−39.0	+4.0	+8.8	+16.5	+5.9	+8.3	+10.9	
		−12.5	−4.2	−11.7	−34.5	−8.5	−6.7	+0.1	−13.5	+0.8	
		−9.1	+1.7	+1.4	−5.0	−1.0	−5.0	−6.5	+0.1	+1.0	
		+3.1	+9.3	+1.2	−9.0	+5.2	−5.3	−5.1	−15.0	+5.4	
Means..............	+1.88	−0.30	+0.77	−5.00	−3.83	+2.78	+1.78	+1.50	−0.60	+2.41	+0.33

EXPEDITION OF 1855.

Nos.	1	2	3	4	5	6	7	8	9	10	11	12
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Correcti'ns	+2.8	+1.8	—15.8	—7.0	+3.5	—0.2	—12.5	—2.9	—6.1	(—34.0)	(—46.2)	(—39.2)
by each	+0.9	—4.2	—2.4	+1.1	—0.2	—5.1	—2.0	+0.4	—2.7	+1.4	+5.7	—3.8
Chronome-	+8.7	+3.2	—5.9	—5.8	—0.1	—1.9	—4.8	—0.9	—1.4	—5.1	—8.5	—0.6
ter to	+1.9	—1.9	+0.3	+0.7	—0.7	+2.4	+0.8	—1.1	—1.8	—8.9	—7.7	—5.3
assumed	+0.9		—4.5	—0.7	—6.4	—0.7	—2.5	+0.2	—3.6	—3.2	—4.3	—2.4
value of λ.			—1.1	+0.3	—5.9	—0.6	—0.5	—1.0	—0.8	+2.8	+2.7	+1.7
Means.....	+3.04	—0.27	—4.90	—1.90	—1.63	—1.02	—3.58	—0.88	—2.73	—2.60	—2.42	—2.08

	13	14	15	16	17	18	19	20	21	22	23	24
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	—6.2	+1.8	—2.6	—0.6	—4.1	—11.2	—2.7	+8.7	+0.0	—1.0	+1.1	—1.3
	—0.2	+4.9	—4.8	—1.4	+2.7	+1.9	—11.5	—0.8	+0.5	—5.3	—0.8	—5.5
	—4.4	+2.5	+0.7	+0.3	+0.5	—11.2	+5.8	—1.5	+5.4	—4.0	+10.8	—2.4
	+6.0	—1.2	—0.5	+0.3	—8.2	+12.0	—1.6	+8.5	+3.4	+0.0	—4.1	—2.3
	—4.2	+2.2	+2.3	+1.8	—2.8	—4.8	—2.4	—1.2	—5.1	+2.4	+0.1	—3.3
	+2.6	—1.4	—6.3	+1.7	—1.7	+3.9	+2.4	+1.2	—11.1	—3.4	—0.3	—1.7
Means.....	—1.07	+1.47	—1.87	+0.35	—2.27	—1.57	—1.67	+2.48	—1.15	—1.88	+1.13	—2.75

	25	26	27	28	29	30	31	32	33	34	35	36
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	+0.5	+3.4	+0.0	+0.3	—7.9	—3.1	—5.8	—3.1	—16.4	+7.0	—0.2	+7.6
	—2.6	—0.4	—0.9	—6.4	—3.7	—9.8	—0.1	—0.2	+4.8	—1.9	+1.9	—5.9
	+1.5	—0.2	—0.2	—2.8	—6.3	+0.1	—4.8	—2.5	—10.6	+4.7	—4.1	+4.7
	—1.0	—4.7	—0.8	—4.2	—0.3	+4.7	+7.6	+0.5	—0.4	—10.1	—0.6	+5.8
	+1.5	—1.1	—0.7	+0.0	—1.5	+0.5	—6.5	—1.8	+0.2	—5.2	+3.5	—0.5
	—0.7		—1.2	—4.6	—0.9	+5.2	+11.9	—2.1	+1.1	+4.3	—0.8	+1.7
Means.....	—0.13	—0.60	—0.63	—2.95	—3.28	—0.40	+0.38	—1.53	—3.55	—0.20	—0.05	+2.23

	37	38	39	40	41	42	43	44	45	46	47	48
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	+5.0	—1.4	—1.5	—3.0	—4.9	—7.2	—1.7	+6.2	—1.4	—7.1	+4.6	—3.0
	+0.1	+2.2	—3.4	—1.5	—1.3	—0.2	—2.2	—0.4	—0.6	+9.8	—3.1	—1.2
	—3.8	—4.1	+0.5	+0.9	—0.2	—0.4	—2.5	—5.7	—1.2	—3.7	—2.3	—9.0
	—1.2	—0.5	—3.9							—6.2	+6.4	—3.3
	—2.7	—2.5	+3.0							—1.6	—4.0	+2.8
										+2.1	+1.0	—3.1
Means.....	—0.52	—1.26	—1.06	—1.20	—2.13	—2.60	—2.13	+0.03	—1.07	—1.12	+0.43	—2.80

Combining the mean corrections given by each chronometer on different voyages, without regard to weights, we have the following results:

	Mean Corr.
Expedition of 1849–50	+ .63s.
Expedition of 1855	—1.18
Final Correction	—0.27

In order to form an estimate of the *liability* to error in any chronometer, we must compare the greatest and the least corrections given by the same chronometer on different voyages. The *average* range for 1849–50 is 19.5s., and for 1855 it is 10.8s. The extreme range is shown in the following table:

Limits	s 55	s 50 to 55	s 45 to 50	s 40 to 45	s 35 to 40	s 30 to 35	s 25 to 30	s 20 to 25	s 15 to 20	s 10 to 15	s 5 to 10	s 0 to 5
						Number of Cases.						
Expedition 1849–50.	0	2	0	1	0	4	1	8	4	4	4	5
1855.	0	1	0	1	1	0	0	2	6	8	19	10

The values given on pages 370 and 371 represent absolute corrections from which the error of rate has been eliminated. It is not possible, therefore, to determine the average error of the daily rate directly from these series. It can be obtained, however, somewhat indirectly from the table given on page 368. It appears from this table that the average range between the greatest and the least values of the average errors at the end of a voyage of 14.8 days is 15.42s., and that the coefficient by which this average error must be multiplied in order to produce the latter value is 2.37. The mean of the average range for the expedition for 1849–50 and that for 1855 is 15.2s., from which we may with tolerable safety assume the average error at the end of a voyage of 15 days to be not far from 6.4s., giving for the average daily error of rate the value ±0.43s., which is almost identical with the values already found on pages 370 and 371.

I add, without details, the results of two other longitude expeditions:

	No. of Chronometers.	Length of Voyage. Days.	Average Error at End of Voyage. s.	Range between greatest and least Value. s.	Coeff.
Cambridge, New York and Chagres	5	12	7.6	26.4	3.5
Eclipse Expedition to Labrador	5	20	3.7	13.1	3.5

Here we have from a limited number of observations the value ±0.41s. for the average error of the daily rate.

It must be remembered that the results so far obtained are *average results obtained from a large number of observations made under the most favorable conditions.* They indicate that a chronometer of average quality is at any time liable to change its daily rate by an amount as great as 0.5s. That this value is probably too small will appear from the following table given by Mr. Hartnup, who made the investigation in 1863. The quantities given represent the error at the end of a voyage of the given duration.

Length of Voyage. No. Mos.	Average error from 1700 Chro.	Best 10 in 100.	2d best 10 in 100.	3d best 10 in 100.	4th best 10 in 100.	5th best 10 in 100.	6th best 10 in 100.	7th best 10 in 100.	8th best 10 in 100.	9th best 10 in 100.	Worst 10 in 100.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	6	0	1	1	2	3	4	5	7	9	25
2	14	0	2	4	5	7	9	11	15	24	62
3	23	1	3	6	9	12	15	18	25	41	101
4	33	1	4	8	13	17	22	28	36	61	143
5	44	1	5	10	17	22	29	39	49	84	187
6	56	2	6	13	21	28	37	50	64	108	233
7	69	2	8	16	25	34	46	62	80	134	280
8	82	3	10	19	30	41	55	74	98	159	328
9	95	3	12	22	35	48	65	86	117	184	376
10	108	4	14	26	40	56	75	98	137	208	425
11	122	4	16	30	46	64	86	111	157	233	474
12	136	5	18	34	52	72	97	124	178	258	524

An error of 524 miles in a ship's position may seem to be rather too large an estimate, but Lord Anson, in a voyage around Cape Horn, did better than this. One of his ships was 500 miles out of her reckoning, and one actually made land on the wrong side of the continent, the error of position being over 600 miles.

In 1871 Mr. Hartnup made an additional investigation, obtaining the following results:

	Extreme Difference of mean daily rate between any 2 weeks	Variation of daily rate due to change of temperature.	Mean of extreme difference between any 2 days of each week.
	s.	*s.*	*s.*
Mean from 297 chronometers	2.19	1.73	0.98
Mean from 40 poorest	6.28	4.55	2.80
Mean excluding 40 poorest	1.56	1.29	0.70

In order to show how largely chronometer errors may be diminished when the rate is given for different temperatures in the form adopted

by Mr. Hartnup, I add the following table, given by him in this connection, derived from the actual performance of a given chronometer:

Mean Daily Rate.

Date.	Temp.=55°.	Temp.=70°.	Temp.=85°.
	s	s	s
April, 1867	— 0.4	+ 1.4	+ 2.3
May, 1868	— 0.6	+ 1.4	+ 2.2
April, 1869	— 1.4	+ 1.7	+ 2.7
November, 1869	— 0.2	+ 1.9	+ 2.8
February, 1871	— 0.2	+ 1.5	+ 2.3

From the first column of Mr. Hartnup's first table I deduce the following values for the error of the daily rate from the mean of 1700 chronometers, assuming the months to be calendar months:

No. months.	Average error of daily rate.	No. months.	Average error of daily rate.
	s		s
1	± 0.80	7	1.31
2	0.93	8	1.37
3	1.02	9	1.41
4	1.10	10	1.44
5	1.17	11	1.48
6	1.24	12	1.51

I am not sure that I have given the correct interpretation to Mr. Hartnup's values, since it is difficult to understand why the error should increase with the time.

From Mr. Hartnup's second table we have the value ± 0.98s. Adopting the mean between the latter value and ±0.46s., the value derived from this discussion, we have finally ±0.72s. as the average daily error of the rate of an average chronometer.

The average coefficient of safety for chronometer errors only derived from this discussion is 3.2. *If, therefore, the navigator has a chronometer of average excellence, he must at the end of twenty days expect from it an average error of* 3.6 *miles, and he must look out for an error of* 3.6m.×3.2, *or* 11.5 *miles.*

It must be borne in mind that these results are independent of the errors of observation with the sextant, which are still to be added.

In estimating the limits within which it is possible to locate the position of a ship at sea by astronomical observations, it is necessary to take into account *all* the errors to which such observations are liable. I shall consider only the method usually employed, viz. the measurement of the altitude of the sun with a sextant at a given time

before it comes to the meridian for *longitude*, and the measurement of its altitude at culmination for *latitude*.

First of all we must estimate the magnitude of the errors to which sextant observations are liable.

They are as follows:

(*a*) Instrumental errors, such as excentricity, errors of graduation, index error, &c. In a first-class sextant errors of this class often exceed one minute of arc.

(*b*) Error in noting the time. No observer at sea pretends to note the time closer than 1s. In fact it is impossible for him to do so. If we assume the low limit of 1s. and multiply by the coefficient 3.5 we find an error from this source amounting to nearly one mile.

(*c*) Error arising from an imperfect sea-horizon. I am convinced that errors from this cause may amount to several miles. In a series of observations made to test the value of Lieut. Beecher's artificial horizon, the range of error was six miles. Nor does the use of an artificial horizon mend the matter, for there is always an undetermined constant between the two methods which ranges from two to eight miles.

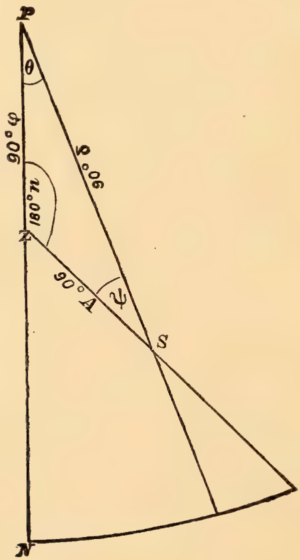
(*d*) Errors arising from the use of approximate data. It is almost universally the practice to take data to the nearest minute of arc, *e. g.* it is the practice to take the sun's diameter as 30′. Many navigators lump all corrections together and call the sum 12′. The error from this source *may* amount to no less than five miles. Another source of error is the failure to use the value of the refraction corresponding with the actual condition of the atmosphere indicated by the thermometer and barometer at the time of observation. The only observations which I can find bearing upon this point were made by Commander Bayfield at Quebec in 1832, the thermometer reading 11° Fahrenheit. He found that the error arising from the use of the mean instead of the actual refractions amounted to three miles.

(*e*) Errors affecting the longitude which depend upon the latitude of the ship and upon the declination and the observed altitude of the sun. The errors arising from this source may be much larger than is generally suspected, and they are the more important because, for the most part, they escape the attention of the navigator.

Let,

$A =$ the observed altitude of the sun.
$\delta =$ the declination of the sun.
$\varphi =$ the latitude of the place of observation.
$\theta =$ the observed hour angle.
$\eta =$ the observed azimuth.
$\psi =$ the angle at the sun.

From the triangle



We obtain

$$\sin. \frac{1}{2}\theta = \sqrt{\frac{\sin. (s-(90^\circ-\delta)) \sin. (s-(90^\circ-\varphi))}{\cos. \delta \cos. \varphi}}$$

where

$$s = \frac{1}{2}[(90^\circ-\delta)+(90^\circ-A)+(90^\circ-\varphi)]$$

$$\sin. \psi = \frac{\sin. \theta \cos. \varphi}{\cos. A} = \frac{\cos. \varphi \sin. \eta}{\cos. \delta}$$

$$\sin. \eta = \frac{\sin. \theta \cos. \delta}{\cos. A}.$$

In order to compute the values of the various errors which may affect θ, we differentiate the general equation:

$$\sin. A = \sin. \varphi \sin. \delta + \cos. \varphi \cos. \delta \cos. \theta .$$

From which

$$\begin{aligned} \cos. A dA = &(\sin. \varphi \cos. \delta - \cos. \varphi \sin. \delta \cos. \theta) d\delta \\ &+ (\sin. \delta \cos. \varphi - \cos. \delta \sin. \varphi \cos. \theta) d\varphi \\ &- \cos. \varphi \cos. \delta \sin. \theta d\theta . \end{aligned}$$

But

$$\begin{aligned} \cos. \delta \sin. \varphi - \sin. \delta \cos. \varphi \cos. \theta &= \cos. A \cos. \psi \\ \sin. \delta \cos. \varphi - \cos. \delta \cos. \theta \sin. \varphi &= - \cos. A \cos. \eta \\ \cos. \varphi \sin. \theta &= \cos. A \sin. \psi . \end{aligned}$$

By substitution we easily find:

$$d\theta = - \frac{dA}{\cos. \varphi \sin. \eta} + \frac{d\delta}{\cos. \delta \text{ tang. } \psi} - \frac{d\varphi}{\cos. \varphi \text{ tang. } \eta}$$

In the proceedings of the American Association for 1881, p. 154, Mr. S. C. Chandler has given the following convenient form to this equation:

Dividing both members of the equation,

$$\cos. \delta \sin. \psi = \cos. \varphi \sin. \eta$$

by $\cos. \psi$, we have:

$$\cos. \delta \text{ tang. } \psi = \frac{\cos. \varphi \sin. \eta}{\cos. \psi}$$

whence $$d\theta = \frac{1}{\cos. \varphi \sin. \eta} [\cos. \psi d\delta - dA - \cos. \eta d\varphi] .$$

From this equation it appears:

(1) That the effect of an error in the observed altitude upon the time will be minimum when $\varphi = 0°$ and $\eta = 90°$, or when the sun is in the prime vertical.

(2) That the effect of an error in δ will be minimum when $\delta = 0°$ and $\psi = 90°$.

(3) That the effect of an error in φ will be minimum when $\varphi = 0°$ and $\eta = 90°$.

As an example we will assume that in a given observation of the sun or of a star the following small errors have been made, viz.:

$$\begin{aligned} d\varphi &= + 1' \\ dA &= + 1' \\ d\delta &= - 1'. \end{aligned}$$

We compute the effect of these errors upon θ in three assumed cases:

	I.	II.	III.
$\varphi =$	$39°54'$	$51°30'$	$70°0'$
$\delta =$	$+17°29'$	$-\ 6°37'$	$+44°0'$
$A =$	$15°54'$	$13°40'$	$63°30'$
$\theta =$	$83°37'$	$58°8'$	$10°10'$
$\eta =$	$80°16'$	$60°15'$	$16°32'$
$\psi =$	$52°26'$	$32°58'$	$7°46'$
$-\dfrac{dA}{\cos.\ \varphi\ \sin.\ \eta} =$	$-1.32'$	$-1.85'$	$-10.27'$
$-\dfrac{d\varphi}{\cos.\ \varphi\ \text{tang.}\ \eta} =$	$-0.22'$	$-0.92'$	$-\ 9.85'$
$+\dfrac{d\delta}{\cos.\ \delta\ \text{tang.}\ \psi} =$	$-0.81'$	$-1.55'$	$-10.19'$
$d\theta =$	$-2.35'$	$-4.32'$	$-30.31'$
$=$	-9.4^s	-17.3^s	-121.2^s

Ordinarily there will be some elimination between $d\varphi$, dA and $d\delta$, but the errors *may* all act in the same direction, as in the examples given. The third example may perhaps be considered an extreme case, but it will serve to show the necessity of a computed table of coefficients which shall serve as a guide in estimating the value of any given observation. An appropriate name for them would be *local coefficients of safety.*

(*f*) Errors arising from the error in the estimated run of the ship between the morning and the noon observations. The morning or afternoon observations give one co-ordinate of position, viz. the longitude; and the noon observations, the other, viz. the latitude. To get both co-ordinates for the same instant requires an allowance for the run of the ship during the intervening time. It is impossible to give any definite estimate of the magnitude of the errors thus introduced, but I suspect they will in general be found to exceed all the other errors combined.

In order to determine the degree of accuracy which may be expected *from the sextant considered as an instrument of observation,* when used by trained and skillful observers, I have collected such observations of this class as were available, both for time and for latitude. In most cases the average error has been found by comparison of the observations *inter se.* The observations made at Willet's Point have

an exceptional value, since they were compared with transit observations made at nearly the same time.

For Latitude.

Observer.	Place of Observation.	Average Error.	Range of Error.	Coeff.
Williams, 1793....	Cambridge	3.6″	14″	3.5
Paine, 1831....	Norfolk, Va..........	9.6	40	4.2
	Richmond............	7.2	31	4.3
	Washington..........	4.6	18	3.9
	Baltimore	5.0	20	4.0
	Providence...........	10.1	50	5.0
	Washington Territory.	7.2	46	6.4
	" "	10.9	41	3.8
1869....	Willet's Point	7.0	24	3.4
1871....	" "	7.8	29	3.7
1872....	" "	9.0	35	3.9
Hall and Tupman.	Malta	10.5	59	5.6
	"	10.2	37	3.6
	"	8.0	34	4.2
Hall and Tupman.	Syracuse	5.0	30	6.0
	"	9.2	36	3.9
	"	7.7	56	7.3
	"	7.1	28	3.9
	"	6.8	28	4.1
	"	6.7	30	4.5
Harkness..........	Des Moines	6.4	47	7.3
Means..........		7.6″	35″	4.6

For Time.

		Average Error.	Range of Error.	Coeff.
		s.	s.	
Hall and Tupman..	Malta.................	1.6	7.3	4.6
	.Syracuse.............	1.0	4.3	4.3
Newcomb	Des Moines...........	0.6	2.6	4.3
Harkness	Des Moines...........	1.1	4.7	4.3
Means..........		1.1	4.7	4.4

For the mean of any number of observations with the sextant, therefore, we must expect an average error of 7.6″ in latitude and of 1.1s. in longitude, and the average liability to error of a single observation will be about 35″ in latitude and 4.7s. in longitude. For sea observations an *additional* coefficient of 3 units will be none too great. No instrument of precision is so liable to constant errors as

the sextant. In all the cases given above these constant errors were thoroughly investigated and the resulting corrections were applied. It is not to be expected that this can be done with sextants used at sea. Even with observations on shore this instrument often acts in a most perverse and unaccountable way. The observations of Williams for the determination of the latitude of Harvard College in 1782–3 are so instructive on the point of agreement *inter se* and disagreement with the truth that I copy his separate results:

Latitude of Harvard College.

From the Sun.	From Fixed Stars.	From the Pole Star.
42° 23′ 22.3″	42° 23′ 25.1″	42° 23′ 28.6″
25.3″	22.9″	27.7″
20.5″	34.1″	
	28.7″	
	36.5″	
	24.2″	
	28.6″	

The mean adopted was 42° 23′ 28.5″. By comparison with the latitude of the observatory this result is 64″ too great, and yet the average deviation from the mean is only 3.6″.

In 1825 Mr. R. T. Paine, perhaps the most skillful observer with the sextant in this country, if not in the world, found the value of the latitude of the Old State House, Boston, to be 42° 20′ 30″, a value which differed 118″ from that given on page 297 of the Transactions of the American Academy, which was also the result of a sextant determination. In 1828–9 194 observations with sextant "Ramsden 1403" gave 20′ 57.8″, and 390 observations with "Ramsden 1375" gave 20′ 57.9″. Yet the mean of 442 observations between 1833 and 1873, divided equally between northern and southern stars, gave 21′ 23″, with a range between greatest and least for 37 dates amounting to only 7.5″. This result is 7″ different from the value derived by Borden in his Trigonometrical Survey of Massachusetts. It gives for the latitude of Harvard College 42° 22′ 15″, the true value being 22′ 48.6″. It is, therefore, 34″ in error, while the earlier value is 59″ in error. Mr. Paine's subsequent observations for the latitude of the Unitarian Church in old Cambridge gave 46.7″, or within 2″ of the truth.

It is well known that there is in general a well defined difference between results derived with the sextant from observations of the sun

and of fixed stars, though Mr. Paine always got substantially identical results. At Syracuse in 1870 Professor Harkness found the latitude from Polaris 7.1″ to be less than from the sun. Professor Hall found a difference of 24.7″. Struve, in his survey of Turkey, found that *Alpha* Aquilae gave latitudes 13″ too large, and that this correction sometimes ran as high as 30.7″.

It is obvious from this brief discussion that there is danger of placing too high an estimate upon the accuracy of the ordinary sextant considered simply as an instrument of observation. It is hardly necessary to say that agreement of repeated readings on a given part of the limb is not necessarily an indication of accuracy. The errors which are usually introduced in the graduation of a sextant belong to a class known as periodic errors. They are formed by successive increments of very minute errors, which it is perhaps impossible to measure individually, but which, by continual additions, may, at a given point on the limb, amount to a quantity several times greater than the error of observation.

The data at hand for assigning a limit to the actual errors of observation with the sextant at sea, taking into account all the errors to which such observations are liable, are exceedingly meagre. For the present I limit myself to the following discussions:

(*a*) Scattered through the volumes of the *Nautical Magazine* will be found records of the determinations of the longitude of various stations, chiefly in the West India Islands, made by various British naval expeditions. The data required are in many cases wanting, but sufficient are available to furnish a fair estimate of the average range of error. The chronometers employed were rated at the Greenwich Observatory at the beginning of the voyage, and the observations for time at the terminal stations were made in the usual way with the sextant. They were probably made on shore, though I can find no definite statement to this effect. Evidently more than usual care was taken with the observations and reductions. It is probable also that a sufficient number of observations were made at each station to eliminate accidental errors in a large measure.

Place of Observation.	Range between results given by different Chron'rs.	Range between results for longitude.	No. of Chron'rs.	No. of Days, Duration of Voyage.
	Miles.	*Miles.*		
Hong Kong ....Singapore, 1849-50....	—	10.0	5	18
" " .... " 1852-53....	—	7.1	5	18
Funchal	2.0	1.5	10	11
Teneriffe	0.2	0.9	11	3
Port Prayo	3.2	1.3	11	10
St. Antonio	9.0	2.6	11	18
Cape Blanco	2.2	2.0	6	3
Cape Bojada	1.8	3.3	7	5
Goree Island	—	2.6	—	—
Great Cayman	1.5	1.7	3	7
Cape St. Antonio	0.6	2.3	3	7
St. Salvador	9.5	18.8	6	6
Martinique	0.8	1.4	3	2
New Providence	3.2	6.1	6	14
Guadaloupe	—	2.2	—	—
St. Martin's	—	4.3	—	—
Alta Vela	—	2.5	—	—
Trinidad	—	3.7	—	—
Barbadoes	5.3	4.9	5	13
Navassa Island	0.8	1.6	3	6
Island de Aves	—	7.5	—	—
New Orleans	—	2.2	—	—
Chagres	1.6	2.0	2	15
Carthagena	4.0	1.7	2	3
St. Martha	2.2	8.3	2	6
Curacoa	—	2.7	—	—
La Guayra	—	3.8	—	—
Archilla	—	2.4	—	—
Marguaritta	—	7.1	—	—
Port Desire	7.5	1.2	7	19
Port Farrin	7.2	—	10	19
Callao	—	7.4	—	—
Valparaiso	6.0	1.4	13	17
Talcahuana	1.5	3.8	4	15
San Carlos	15.1	31.6	20	27
" "	6.8	10.9	18	12
Panama	—	3.3	—	—
Guayquil	—	7.6	—	—
For 36 Stations...... Mean	4.2	5.0	—	11
For 36 Stations...... Range	14.8	29.7	—	—
For 36 Stations...... Coefficient	3.5	5.9	—	—

(*b*) During the spring and summer of 1880 Officer W. H. Bacon, of the Cunard steamer "Scythia," kindly undertook for me a series of systematic observations from which the relative errors could be determined with considerable certainty. A complete series for a single day consisted of five sights at intervals of fifteen minutes, about 8 o'clock in the morning, five sights in the neighborhood of 11 o'clock, and five sights at the corresponding hours in the afternoon. Observations were also made when the ship was in known positions as often as possible.

This series of observations has an exceptional value on account of the conscientious fidelity with which the programme was adhered to and of the skill with which they were made. The relative errors were determined by comparing each position with the mean of the series, the rate being determined both from the morning and afternoon observations and from the log.

The results obtained are found in the following table:

LIMITS IN MILES.	Average Error from Observations at 9h and 3h.	Average Error from Log at 9h and 3h.	Average Error from Observations at 11h and 1h.	Average Error from Log at 11h and 1h.	Difference between Observation and Log at 9h and 3h.	Difference between Observation and Log at 11h and 1h.
	No Cases.	No Cases.	No. Cases.	No. Cases.	No. Cases.	No. Cases.
0.0.... 0.5..............	1	0	0	0	7	6
0.5.... 1.0..............	0	6	2	3	1	2
1.0.... 1.5..............	8	13	3	5	3	3
1.5.... 2.0..............	4	5	3	3	3	2
2.0.... 2.5..............	6	4	6	5	2	3
2.5.... 3.0..............	2	1	3	4	1	0
3.0.... 3.5..............	2	2	6	5	7	2
3.5.... 4.0..............	4	1	4	5	1	2
4.0.... 5.0..............	1	3	6	5	4	4
5.0.... 6.0..............	0	0	2	1	1	5
6.0.... 7.0..............	0	0	2	1	2	2
7.0.... 8.0..............	1	1	0	1	1	1
8.0.... 9.0..............	2	0	1	1	0	2
9.0....10.0..............	0	1	0	0	1	2
10.0....11.0..............	0	0	0	0	1	1
11.0....12.0..............	0	0	0	0	2	1
12.0+	1	1	0	0	0	0

It will be seen that the results from these two investigations do not materially differ from those previously found. In fact, whatever the line of investigation pursued, we reach substantially the same conclusion, viz. that the average error of a single observation at sea is not far from three miles, and that the average coefficient by which this number must be multiplied in order to provide for every contingency of danger is 3.5.

NAVAL INSTITUTE, ANNAPOLIS, MD.

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THE COEFFICIENT OF SAFETY IN NAVIGATION.

By COMMANDER P. F. HARRINGTON, U. S. N.

In the current volume of the Proceedings of the Naval Institute there appears an essay by Professor W. A. Rogers, of the Cambridge Observatory, on the Coefficient of Safety in Navigation, which is remarkable for the extent and thoroughness of its investigations, and valuable in the application of its results to the practice of navigation. The essay is based upon investigations to which the navy has not contributed, and it becomes important to consider the application of its conclusions to the ordinary course of navigation of men-of-war.

The coefficient of safety is defined as a number by which the average error of a ship's position should be multiplied in order to obtain the limit of possible error. If a ship be navigated in consideration of the limit so obtained, her safety is assured, so far as it depends upon an estimation of position. As determined by Professor Rogers, the coefficient is not strictly the ratio between the average error and the extreme error; but it may be so regarded in practice, upon the assumption that the least error in a series approaches nearly to zero.

In order to value the final effect upon the computed co-ordinates of a ship's position, the errors to which the *data* are liable may be classed and considered with regard to their influence in the computations and upon the estimated progress of a ship subsequent to the astronomical determination of her position. Those errors which affect the altitude as an element of the *data*, in observations at sea, are: first, instrumental errors, or those of the sextant; secondly, errors of observation; and, thirdly, errors of the tabulated dip and refraction.

The constant errors of the sextant are those of excentricity and graduation; and there are others, of a variable nature, which are due to the surfaces of the index and shade glasses not being parallel, to the setting of the telescope in a plane inclined to that of the instrument, to small inclinations of the index and horizon glasses, to an increase of the apparent diameter of the sun arising from the feeble power of the telescope, and to the effects of changes in the temperature. No error can arise from a prismatic form of the horizon glass. These errors differ in value for different sextants and at different times in the same sextant, and the total amount may or may not be inconsiderable. On shore, they may be examined and the corrections partially ascertained. Professor Rogers finds, from a series of observations on shore, a value of 7.6″ for the average error in latitude and of 1.1s in longitude, and a value of the coefficient of four and seven tenths. In these observations the errors of the sextants were thoroughly investigated and the corrections were applied; but the results are open to the objection that they were obtained by a comparison with the mean of the series and not with a fixed value. The suggestion that the coefficient should be increased by three units for single observations at sea is not unreasonable; and from this we find the average liability to error at sea exceeding one minute of arc. It does not appear that the values reported are due entirely to the sextant and have reference to the altitudes of the bodies observed; but the character of the observations, of bodies on the meridian for latitude and near the prime vertical for longitude, justifies the assignment of the error to the sextant, since the error of the instrument entered directly into the altitude and was transmitted in its full amount to the computed latitude, or to the longitude with but little alteration, and since no other element could be erroneous. Other considerations, already stated, support the conclusion that the error of altitude at sea, due to the sextant alone, may exceed one minute.

The errors of observation include the inaccurate valuation of the index error, the personal error in the observation itself, the error of making the contact without the middle of the field of the telescope, and the special error of observation when the motion of the ship is considerable. The error arising from defective shade glasses may be avoided by using a shade cap over the eye-glass of the telescope. A screen of card board may be fitted over the eye-piece to shield the eye from the glare of rays, other than those passing through the

telescope. The total value of the errors of observation is neglected, necessarily, at sea, nor does it appear how these and the sextant errors may be considered except by the use of a coefficient of safety.

The most serious error is that of the tabulated dip. As the ship rises and falls with the swell of the sea, it is difficult to fix the height of the observer's eye; and, at moderate elevations, an error of four feet in the estimated height of the eye causes an error of about half a minute in the apparent altitude. Moreover, the dip is tabulated for a mean condition of the atmosphere. The path of a horizontal ray of light near the earth's surface varies greatly with the state of the atmosphere. From this cause the tabulated dip cannot be relied upon more closely than two minutes, when the eye is not elevated more than sixteen feet. The curvature of a ray of light in air at any point in its course depends upon the pressure, temperature, and rate of change of temperature; the third condition being in general the most important. When the temperatures of the water and air differ greatly, the variation of the apparent place of the sea horizon from its mean place becomes extraordinary. Variations of four minutes have been observed frequently, by the use of a dip sector or prismatic sextant, in comparison with a common sextant, and larger values have been found. The apparent horizon is depressed below or elevated above its mean place, according as the sea is warmer or colder than the air. For example, a large increase in the dip may be expected when traversing the Gulf stream in cold weather. The extreme case of displacement in a downward direction is illustrated by the *mirage*, where rays of lights pass from objects above the horizon, obliquely at first towards the earth, through successive layers of air of rapidly decreasing density and refracting power, and subsequently upwards, through air of increasing density, to the eye of the observer. The inverted image of the distant object is thus formed, while another image in its erect position is seen through the medium of rays passing more directly to the eye of the observer. In the polar regions images of distant objects sometimes appear lying in the air. This occurs when there is an extreme refraction in the contrary direction to that which causes the *mirage*, the layers of air near the sea decreasing rapidly in density with an increasing altitude. The tabulated refraction, which affects the altitude, also becomes more uncertain as the altitude of the body decreases. These errors of dip and refraction may be partially compensated by attention to the corrections for pressure and temperature of the air. The tables, however, are not perfect, nor

do they always agree. Two tables, now in general use, differ three minutes as to the amount of refraction near the horizon, for a mean height of the barometer and thermometer.

Some function of the algebraic sum of these errors affecting the altitude enters into every computation for position at sea, and the error in marking the time of an observation or of a comparison enters directly into every determination of longitude. What, then, is the probable average error of an apparent altitude taken under favorable circumstances at sea? Will it fall below two minutes? Or, rather, can the navigator feel assured that it is not greater? It may be said that these errors and others yet to be noted will offset each other generally to some extent; but by what test may this be known in practice, and what part of the uncertainty is removed?

With respect to the latitude, when it becomes an element of the *data*, it must be remembered that its accuracy depends, primarily, upon observations of the character already described, and, secondarily, upon the closeness with which the run of the ship is noted. The same is true of the longitude, whenever it enters as a part of the *data* in any observation off the meridian; and it will contain also the error in the assumed longitude of the place of rating, the error in the original determination of the chronometer correction, and the accumulated error of the rate; and some function of the algebraic sum of these will enter into the computation. If the longitude is sought, the computed value will contain directly the errors last enumerated, besides that resulting from the computation.

It has been shown by Professor Rogers that it is difficult to determine accurately, even with excellent instruments and under the most favorable circumstances, the geographical position of a point on the earth's surface. The values of the coefficient, obtained from series of observations on shore, will be received with surprise, but they must be accepted as true. What degree of dependence then shall be placed upon the result of a single set of observations at sea, affected by all the errors enumerated and in an unknown direction? Is it probable that the naval officer, using the best instruments and exercising the greatest care and selection in observations, computations, and methods of navigation, reduces the average and extreme errors of position to exceptionally small values? It may be asserted that the observations of naval officers are particularly accurate, but that is all that can be affirmed; and that the true position of a ship at sea is ever obtained from astronomical sources is exceedingly doubtful.

Formulas and tables, by which the effect of the errors referred to may be considered, will be found in any good work on Navigation, and there are many practical methods of reaching the same end; but it may be interesting to notice, briefly, some rules by the observance of which the errors themselves may be reduced in amount and the general accuracy of the determinations may be improved.

Attention should be paid first to the situation of chronometers on board ship, with respect to the motion of the ship and to the proximity of any particular magnetic influences. Extreme motion of the ship disturbs the vibration of the chronometer balance and produces a change of rate. The balance may acquire a magnetic polarity; and, in order to avoid an error arising from this cause, the chronometers should be placed with the twelve hours mark of the face in the fore-and-aft line of the ship, and they should not be removed for any purpose. The rates should be found for the constant position of the chronometers. When proper precautions have been observed to avoid these disturbing agents and also the danger of rude shocks, it is conceded that variations in the rate are caused almost entirely by changes of temperature. It is desirable, therefore, to guard against sudden and extreme changes, and, whenever practicable, to provide a place of uniform temperature. On board ship this is almost impossible, and the navigator must rely upon a close study of the chronometer and thermometer and of the law which connects their motions. During the progress of a cruise there will be found a gradual acceleration of the chronometer rate, which is independent of the effect of temperature. This is due to the thickening of the oil, which diminishes the amplitude of the vibrations of the balance. The amount of this change is peculiar to to each chronometer, and can be found only by experiment. Chronometers for the use of the navy are issued from the Naval Observatory at Washington, and are accompanied by a list of rates for different mean temperatures, found by actual trial and record. With this list before him the navigator will be able to anticipate in an approximate degree the changes of rates, by attending to the daily temperatures of the chronometer room and to the record of comparisons. Every chronometer has its own law of change; and, further, the alteration of rate is not contemporaneous with but follows at different periods the changes of temperature. If this important duty of studying the character of each chronometer is neglected, a belt of possible error in longitude results from the average daily error and coefficient

of safety for chronometers. The average daily error is $\pm$ 0.72s, and the value of the coefficient three units and two tenths. These quantities appear very large, but they are deduced from extensive and comprehensive examinations of chronometers, by a course of computation which offers no ground of objection.

The error and rate of a chronometer should be found from transit observations, or from equal altitudes of the same body when on opposite sides of the meridian. The whole error of longitude of the point of observation will enter into the chronometer error; but the rate may be closely determined by these methods, though the latitude and longitude are known only to an approximate degree. When such observations are impossible, the error may be found from single altitudes of the same body, on opposite sides of the meridian and near the same altitude, the mean of the results being adopted; and the rate from single observations of the same body, provided the conditions of atmosphere, altitude, and *azimuth* are not very different upon the two occasions. The error cannot be determined correctly from single observations of a body off the meridian. It seems unnecessary to argue that the sea horizon should not be employed in this work.

At sea, if the azimuth, or true bearing, of the body observed is less than forty-five or greater than one hundred and thirty-five degrees, the latitude should be computed from the observed altitude and the longitude by account. The error in the latitude, which results from the errors of the *data*, decreases as the body approaches the meridian in azimuth, and, when the body is on the meridian, it depends upon and is equal to the error in altitude. It should be remembered, however, that the *maximum* altitude of the sun differs from the meridian altitude, when the motion of the sun in declination is most rapid and when the ship's rate of movement in latitude is large, by an amount which, in certain latitudes, may exceed one minute. In the case of the moon, this difference may be much greater near the periods when the moon's declination becomes zero.

If the true bearing of the body is more than forty-five degrees and less than one hundred and thirty-five degrees from the meridian, the longitude should be the co-ordinate sought. When the body is on the prime vertical, a small error in the latitude is of no importance, and the error of altitude has its least effect, or, nearly, its amount converted into time. The error of the chronometer correction cannot be eliminated.

When the declination of the sun and the latitude are nearly equal and of the same name, the method of equal altitudes of the sun for longitude is highly recommended. The altitudes may be observed very near noon; and, in connection with the meridian altitude, the latitude and longitude are found almost simultaneously. If equal altitudes are lost, by reason of passing clouds, Littrow's method is still available, and is equally simple in computation.

It is recommended in Raper's Navigation that, when the altitude of the body is sufficient, it should be observed both from the opposite point of the horizon and from that under it, by the common sextant. Half the difference of the *readings* should be the apparent zenith distance of the body, eliminating the dip and the errors of the instrument. This assumes that the dip is the same at opposite points of the horizon. The difficulty of this observation would probably cause erroneous results, but it is suggested for trial, in deference to the high authority cited.

Observations at night are very unreliable, from the obscurity of the horizon and the difficulty of reading the sextant. But, during twilight, observations may be made which will reduce the uncertainty of the ship's position. The local time may then be found accurately from altitudes of stars east and west of the meridian and having similar zenith distances and azimuths, and a very close value of the latitude from altitudes of stars upon or near the meridian north and south of the zenith.

It is an obvious consequence of the preceding statements that the computation of position at sea to seconds of arc is unnecessary, so far as the accuracy of results is concerned, and that it may produce an appearance of precision and correctness not inherent in the methods. Aside from this tendency to engender an unreasoning confidence in the results, the habit of close figuring is a valuable one; and the use of seconds, in this class of computations, accords nearly with the usual practice of employing units of an order one lower than that required. Attention to minute details is almost essential to good navigation; and such attention leads at once to a just discrimination as to the degree of computation necessary.

When approaching a coast, off which the depths of water and character of the bottom are well marked, the lead becomes an invaluable aid to navigation. A good sounding and a line of position, taken together, are almost as useful as a lighthouse to an intelligent navigator. The following method of navigation by the lead is described

by Sir William Thomson. "Take a long slip of card, or stiff paper, and mark along one edge of it points at successive distances from one another, equal, according to the scale of the chart, to the actual distances estimated as having been run by the ship in the intervals between successive soundings. If the ship has run a straight course, the edge of the card must be straight, but if there has been any change of direction in the course, the card must be cut with a corresponding deviation. At each of the points thus marked on the edge, write on the card the depth and character of the bottom found by the lead. Then place the card on the chart, and slip it about until you find an agreement between the soundings marked on the chart and the series written on the card. The slight ups and downs of the bottom, even if they be no more than to produce differences of five or six fathoms in depths of, say, from five-and-thirty to fifty fathoms, interpreted with aid from the character of the bottom brought up, give, when this method is practiced with sufficient assiduity, an admirably satisfactory certainty as to the course over which the ship has passed."

The errors incident to the progress of a ship must now be considered. Imperfect steering, unknown or incorrectly estimated currents and leeway, and errors in the compass deviations, generally result in some wandering from the given course. The distance sailed is not accurately known, nor is it likely, in the absence of means of finding the set and drift of the current at all times, that the run of the ship can ever be implicitly relied upon. From the Dutchman's log to the patent log, the instruments have all failed to record exactly the progress of the ship. Napier's pressure log and Hogg's speed indicator show the rate of speed at any instant with accuracy; but for purposes of navigation we must look to improvements in those instruments which measure the total distance run by the ship, rather than to an indicator of the momentary speed. It is possible, however, that the pressure log, or the speed indicator, may be made to record continuously the rate of speed, by a mechanism similar to that of a self-registering tide-gauge, forming a speed curve which would present the rate at any instant and, by simple measurements, the distance run, to a high degree of accuracy. In further consideration of the coefficient of safety, it may be assumed that the average error in the course is one quarter of a point, and that of the distance one twentieth of the run by log. It is difficult to state the possible range of error from these causes; but every naval officer can recall occasions

when the place of the ship by account, after a run of a hundred miles, could not be depended upon within twenty miles in any direction, although good observations had been obtained at the beginning of the run. Yet this uncertainty corresponds to an error of one point in the course, or of one mile in a distance of five. Fortunately, in most instances, as in gales or known currents, the uncertainty becomes apparent and induces additional caution.

Of the large number of wrecks from preventable causes, and particularly of new iron or composite ships, the loss of a considerable *per centum* is caused by compass errors, such as unknown deviation due to change in the magnetic condition of the ship, to a change in magnetic latitude, to neglect of the heeling error, and to a change of course in high latitudes after the ship has sailed on one course for a long time. The causes of compass deviations and the character and degree of their changes are now well understood; and the losses from compass errors might be assigned justly to that class which includes ignorance or incompetence of the persons in charge of the vessels. The accomplished navigator foresees these subtle changes, understands their amount and effect, and provides the correction or remedy. The ignorant navigator very often makes a good guess, and sometimes makes a bad one and runs his ship by it into danger. But it cannot be doubted that a majority of vessels of the class here referred to, and many others, would have avoided disaster by the use of a coefficient of safety.

The erroneous position of the coast-line upon a chart may be considered, with regard to an approaching vessel, as represented by an equal error in the position of the vessel and in the opposite direction. For example, if a coast is five miles in longitude eastward of its place as represented on the chart, it is relatively the same as if the ship's actual place is five miles in longitude westward of its computed position by chronometer. In effect, the error in a coast-line may be dealt with as an error in the ship's position, and it thus becomes connected with the value of the coefficient of safety. The determination of longitudes by electric telegraph, by Lieut. Commanders F. M. Green and C. H. Davis, under the direction of the Bureau of Navigation, will be of incalculable value to the commerce of the world, in multiplying points of reference for chronometer errors and in the correction of charts.

Considering all the various sources of error, the average error of the ship's position at sea, as found from a single astronomical observa-

tion, is required, and also the average hourly increase in this quantity due to causes operating subsequent to the astronomical determination. The application of a coefficient will then show upon a chart the circle of possible error; and, in approaching or passing a danger, the course of the ship should be laid from that part of the circle nearest to the danger, and pursued more particularly as the character of the soundings, currents, and absence of lights, render uncertain the proximity of the danger. The extreme errors are most difficult to ascertain at sea, from the want of a true standard to which to refer the computed positions, at the times these errors are likely to occur. It seems, therefore, the best course to adopt a value of the coefficient, say of four units, based upon the discussions of Professor Rogers, and to approximate to the amount of the average error. Every navigator may find a value of this error; first, in the manner indicated at the close of the essay, and, more accurately, by a comparison of computed positions with those found simultaneously with the observations, by cross bearings, or by horizontal angles by sextant between three points when passing well established landmarks. These comparisons should be obtained under all possible conditions, of atmosphere, of height of the eye, of altitude and azimuth of the body, and of motion of the ship. When a lighthouse or other good landmark is first sighted in the course of a voyage, its correct magnetic bearing and distance should be carefully determined and compared with the computed or chart bearing and distance, and in this manner the error in position at the end of a run may be found. For example, if a known point of land is seen at a true distance of twenty miles upon a magnetic bearing which differs one point from the chart bearing (corrected for deviation but not for variation), the error of position is not less than three and nine-tenths miles. If the bearings coincide, the computed distance may be in error, and the amount of the error may be ascertained frequently by attention to the progress of the ship and the change in the bearing of the object. A table of average errors could then be formed, in which the classification should regard mean altitudes, latitudes, height of the observer's eye, and variations of the atmosphere; and such results would be very useful, if the work be conducted systematically and reported in detail. Observations when at anchor in a roadstead, where there is a large arc of sea horizon visible, ought not to be included in such an investigation, as the nearness of the land will modify the condition of the atmosphere, and as the circumstances are different in other respects from

those desired. Even in a roadstead, a series of observations would produce interesting results, and would probably lead most people to join Professor Rogers, in the respect he feels for the judgment of that sea-captain, who placed the average error of a ship's position at five miles.

The use of the coefficient is not very dissimilar to the best characteristic of Sumner's method, in connection with a single line of position. The prudent navigator assumes that his ship is not at the point on the chart indicated by the computed latitude and longitude, nor even upon the line of position, but at any point within a belt formed by drawing parallels on each side of the line of position at such a distance as to include all the probable errors of altitude, chronometer, etc., incident to the particular circumstances of his observation and progress.

The essay of Professor Rogers will be read with profound interest by naval officers. It indicates a field of investigation in which the efforts of naval officers may be usefully exerted. Its practical conclusions and warning ought to be impressed upon every man who is permitted to lay a vessel's course. The term Coefficient of Safety in Navigation should be received into the vocabulary of nautical phrases, to be associated in the mind of the navigator with the errors which he must estimate and correct, and to become a momentary element in that watchfulness which is the price, though not the assurance, of safety upon the sea.

A Letter from Hon. R. B. Forbes to Prof. W. A. Rogers.

Milton, January 10, 1882.

Prof. W. A. Rogers, Cambridge, Mass.

Dear Sir: I am a member of the Naval Institute, and I have read your interesting paper published in Number 3, Volume 7, of the Proceedings.

I agree with you that many accidents to ships are the result of over-confidence. A man takes his sights, works up, and places himself in a certain spot on his chart; he says here I am and I cannot be anywhere else. Now, every careful navigator when nearing land or places where devious currents are known to exist, as on the edges of the Gulf Stream, should plot his position by assuming several latitudes in working his time, and he should assume that he may have been set out of his course one way or the other, and so, instead of putting down a single dot for his place, and running as if he was perfectly sure of that position, he should describe a circle round his assumed position and make a course that would be safe if he was on one extreme verge or the other.

How many navigators do this?

The majority, full of experience and confidence, often get into trouble by over-confidence. Some good practical seamen running by a single chronometer, and never taking lunars, fall into errors by placing too much confidence in the chronometer and in their observations by sun, moon, or stars, for latitude. In the course of my experience as a navigator, relying on Bowditch's tables, without knowing how they were made up and not caring to know, I was in the habit on clear nights of taking the meridional altitudes of every star of any magnitude, both north and south. Sometimes I could only find the name of the star by noting its bearing from some well-known star or planet, and then by referring to my chart of the heavens I could find its name. I also was in the habit of moving my index, and bringing my star (now on or near the meridian) down several times and taking the mean. Considering the uncertainty of the horizon at night, I considered this absolutely necessary: whereas most persons, full of over-confidence in their eyes and judgment, take a single sight and work by it. By thus taking sights at night I frequently knew my correct place when, by reason of squalls or clouds, I could not get a meridional altitude of the sun the day before or the next day.

Confidence is all very well when founded on good grounds. I once ran into the Rio de la Plata during thick weather, with the wind at NE, making the land near Ensenada, well up the river, when the fog lifted, at about 10 A. M. I had seen no land since sighting the Cape of Good Hope, or the land about

Cape Lagullas. My chief officer was a man of considerable experience and a good navigator, and he had been into the La Plata several times, and was full of yarns as to the devious currents, the bad shoals, and the pamperos. He thought that I, a novice in that region, was running a great risk. But I had taken soundings off to the NE of Cape St. Mary's the night before, and also near the English Bank and off Point Indio, and by altering my course in and off shore, so as to keep in three fathoms, my draft of water being fourteen feet, I ran up the river under full sail in a dark night, when there were no lights as now, except on Flores or Lobos. To tell the naked fact that I ran from Cape Lagullas to Ensenada, seventy or eighty miles up the La Plata, without seeing any land, would generally be thought the result of over-confidence. So much for over-confidence which I know has led many into danger.

My principal object in addressing you is to give you some of the results of my experience in local attraction in ships both of wood and iron, which has been the cause of many wrecks. In the early days of 1843 or 1844, I built three steamers of wood, the Midas, the Edith, and the Massachusetts. I had at that day heard very little about local attraction; I had heard little or nothing about Scoresby, Barlow, Airy, or Sabine. I had not taken any measures to correct local attraction in the Edith, simply because I knew absolutely nothing about this insidious enemy. I sailed in her one fine afternoon in winter, bound to New York. Consulting the pilot on the way down the harbor and bay as to the correctness of my compasses, an error was discovered perhaps amounting to one point, heading easterly, carrying us too much to the north; this was duly noted and considered as a fact *for all courses;* by-and-bye, after running by buoys and bearings over Nantucket Shoals and Vineyard Sound, we encountered a snow storm and made a harbor under Dutch Island. I should say that we had a Boston pilot on board, as well as one of the most experienced sound pilots, Captain Daggett. When we came to head to the westward it was found that the error which was noted going down towards Cape Cod, which carried us to the left, when applied to a westerly course was all wrong. We were all puzzled; but in a blinding snow storm in a new steamer, fully rigged, manned by riggers hired by the run, and commanded by a man named Lewis, who had never been in charge of a steamer and had no idea of local attraction, we were too glad to get snug to anchor and had too much on our hands to commence the study of local attraction. It was evening when we came to anchor at Dutch Island. The storm continued until morning, when the wind shifted to the WNW, with cold winds; the bark was loaded with ice and snow; after clearing this off, late in the day we got under way for the sound, under steam and sail. While daylight lasted all went on well; the pilots and the captain did their best beating to the westward, and probably taking little note of the action of the compasses; pilots under like circumstances look at the land and tack when they think they are in the place to do so. They did not at that day know anything about local attraction. The light at Watch Hill had been seen early in the evening, Block Island Light also; about 8 P. M., just as we were going to supper, I requested Captain Lewis to give me the bearings of Block Island, Watch Hill, and any other lights. I plotted these bearings on the chart and could make nothing appear right; about this time

we tacked to the WSW. Other bearings then taken made still more confusion and I felt disposed to believe Captain Lewis had not given the right bearings. I called Captain Daggett and I said that I could not make out our position by the bearings, and I thought our compasses were all wrong; he agreed to this and said, "Make yourself easy, I have seen Watch Hill, Block Island, Fisher's Island, and Stonington, and we are now heading to clear Little Gull." We were beating under nearly all sail and steam, and everything except the compass seemed to be going right, and we went to supper. We had scarcely commenced our meal when she struck and nearly stopped, bumping hard; I ran up and heard Daggett cry "Let go the anchor," which is what the Chinese pilots do when they get into trouble. Mr. Fowler, the Boston pilot, cried, "Hold on the anchor, about ship, give her steam;" and after a few bumps she came round, and it was then determined that Daggett *had been running to pass Montauk*, leaving it on his left, *instead of Little Gull Light*. We had struck on Shagawanoc reef, near Montauk, or possibly on some shoal since located between Montauk and Little Gull. Now, with the chart before one, knowing that in a clear winter's night all the lights had been seen, it would seem to be quite impossible for any man in his senses to be so completely lost. It would seem quite impossible that two pilots and the captain, all constantly on the watch, and one passenger (myself), who thought he knew more than all of them, should get into such a scrape. After getting fairly into the sound we discussed the subject. Daggett said that he had been deceived by the snow on the land, and that he had calculated on a strong tide setting us to windward, when in fact it was setting us dead to leeward. We also found out that in tacking very close hauled she did not appear to lay up by compass within less than 7½ points, although we were quite sure she lay within 5 or 5½. If we had been beating to the eastward the compass would have shown that we lay up inside of 4 points! I then first seriously began to study local attraction.

In a year or two after, I left Boston in the Massachusetts for New York; going down the bay we found a considerable error in the compass, but I think it was in the opposite direction from the Edith's error. We went outside of Nantucket and Long Island. We had an experienced New York pilot on board, and when, during the night, he was standing in for Fire Island Light and could not find it, he assumed that he must be right and that Fire Island Light was out, and continued standing on; when daylight came, we found ourselves off Barnegat! In fact we were so far to the southward that when we shaped our course for Sandy Hook we set our starboard studding-sails to a breeze from about ESE.

Not very long after this experience, the iron towboat the R. B. Forbes had been found almost useless in thick weather, owing to her being almost all iron. In running in for Broad Sound in a fog, the master, Griffith Morris, ran on to the ledge off the NE end of the Graves, and knocked a hole in her bow compartment, which, to use the captain's liberal phrase, was big enough to carry in a wheelbarrow. She backed off and came to her dock somewhat by the head, owing to water in the forward compartment. Morris had not had the benefit of a liberal education, excepting in rope yarns and piloting. He began to study local attraction and to make experiments with magnets, and he soon

found means to make the compass of his iron pot, in the wheelhouse and partly over the boiler, quite correct, to give him confidence in his courses; he repeatedly towed valuable ships to New York through the sound in bad weather, and never met with any accident. About this time, say in 1846 or '47, I was made aware of Morris's *pretensions*, and I had many conferences with him. Among other things Morris said, that when steam was up and the wind blowing from aft, carrying the heat from the funnel into the wheelhouse, he had to make some allowances: this coincides with what is said on page 226, quoting Dr. Scoresby.

At my instigation, the Navy Department permitted Morris to correct the Merrimack, then fitting out under Captain Pendergrast; he was not allowed to swing the ship, and he applied his corrections at the sheers; when ready for sea, I accompanied her in my namesake outside the Light, where she was turned round, bearings taken and all pronounced to be right. Morris was to be paid after six months' trial; at the end of that time he received his pay, the captain and his navigating officer attesting to the accuracy of her compass, between about 50° and 10° north latitude. The ship went round Cape Horn under Commodore Long, and on arrival at San Francisco he reported to me that his compass was all right, both in north and south latitude. I have no actual proof of the existing error before Morris applied his corrections, but he informed me that lying at the sheers he estimated it on certain headings as much as two points. After hearing from Commodore Long, and desiring to have Morris tried on some other ship, I procured an order to correct the Minnesota, fitting out for China, under Commodore Dupont; Morris went to Norfolk, and finding an iron spindle to the steering wheel near the binnacle acting as an obstruction, asked to have it changed for a composition spindle; red tape refused on the ground that that iron spindle was customary, and it was not until I had examined ships at Boston that I discovered composition was the right thing there, and, by stating this to Commodore Charles Morris, the desired change was made, and Commodore Dupont reported, from China, "compass correct, north and south."

Calling again on the Government to permit Morris to correct other ships, I was told by the officer at the proper bureau at Washington (I think it was Ingraham) that the report from the Merrimack was unfavorable. I requested a copy of it, and I found that the maximum error was stated as *two and one-half degrees*, and this error was arrived at by azimuth and amplitude, and by consulting a magnetic English chart *eight years old*. I said to the chief, This is a complete vindication of Morris; compasses, as usual, placed in binnacles, out of the line of the keel, and three or four feet apart, differ, almost always, as much as this. It was also stated in the report that Morris "*had failed to isolate the compass*," inasmuch as moving the after pivot gun it was disturbed. As Captain Morris had never pretended to annul terrestrial magnetism, or to make his compass correct when guns were moved near it, this statement showed that the young officer of the Merrimack had not studied the subject as it is now studied at Annapolis. Subsequently, Morris corrected several of the public ships, and many merchant vessels: also, two iron steamers sent to India, and they were reported all right in both hemispheres. Captain L. M. Golds-

borough, one of the best educated officers, said when the Merrimack and the Minnesota arrive at or near to the equator, Morris's corrections, good for north latitude, *would be all wrong.*

It had been long conceded by the savans of Europe that an iron vessel corrected by magnets and feeders of soft iron at London, would be all wrong in the southern hemisphere, or reversed, as stated on page 226, in regard to the Royal Charter in which Scoresby embarked. I had received a letter from the captain of a steamer of iron, running to the St. Lawrence, stating that his ship had been swung and that he had compasses at several points which were correct in England, but which were all wrong on arrival at or near the river. In short, no one was believed who said that any one could by magnets or otherwise make a compass to tell the truth in both hemispheres, and without any change of the appliances. Now for my experience. The iron yacht Edith's compass where I wished to put it was wholly useless: I was to go to sea the next day and I called on Morris to correct her; he said that he would do so for the cruise, and add to his means something more when he could swing her more thoroughly: he placed the compass on the slide of the companion-way, lighting it from the cabin by plate glass set under the compass. Morris went to sea with us, and we found the compass correct on all courses when the companion slide was closed. I ran that boat two summers without any changes, and then sent her to the La Plata, and her compass was correct all the way. I navigated her for several months in that country, and all proved correct, or if not right, I had not discovered the error.

The same year, namely, November, 1858, I left here in the iron brig Nankin for the La Plata; in examining her for deviation of her compass in the place assigned to it, near the iron wheel on the trunk cabin, there were found errors on some headings amounting to more than *ten points;* she was corrected by Captain Morris, and when we sailed, the north star and the sun's bearing, at noon, were carefully watched both by the captain and myself, and no error was found; no change of the magnets was made, and no error was discovered on crossing the equator, or anywhere on the way. The brig went to China, and there loaded for England. The captain was ordered to watch his compass carefully, and to report any change; on arrival in China he reported that in running down his easting, in latitude about 40°, he found an error of about one point, but he gave no details; on arrival near Java the error vanished: I demanded particulars, and I found that a pivot gun, which was mounted abaft the wheel, had been stowed below on reaching the stormy latitude; I found also that the galvanized boats, which were hung to the davits, had been taken in and stowed somewhere on the trunk; they were replaced on nearing Java, hence the error and its cure. From the time of her leaving China for London, and her return to China under a new captain, I heard nothing of errors in her compass, although I received copies of her logs.

In the same year, 1858, I sent an iron steamer to the La Plata, she was corrected by Morris, and she went out all right as reported by Captain Breck. During the late war I sent the iron steamer Pembroke to China, under Captain J. A. Cunningham, and she went like the others without any trouble from local attraction. All these vessels had no table of errors on certain headings, they

were absolutely correct for all purposes of safe navigation. In Europe I have not heard of any vessels corrected for local attraction which have not had a table of errors for almost all headings, excepting perhaps when going nearly north or south, and it has been declared over and over again that no iron vessel could be corrected for both hemispheres. When Captain Morris was engaged actively in correcting vessels for local attraction, I requested Professor W. B. Rogers to call on him with a view of getting him to explain his method: the Captain said it would result in nothing, as he could not explain to a scientist in scientific terms what he aimed to do; after an interview Mr. Rogers said to me that while he could not explain the method, he was satisfied that *Morris was no charlatan*, and he added that he had learned something new to him in regard to magnetism and local attraction.

Another remarkable case was the iron brig Mahlon Betts, built at Wilmington, Delaware, for a coaster; when ready for sea it was discovered that her compass, situated in the after part of the trunk cabin, was of no more use than a Hingham box; she came to Boston and Captain Morris was called on to correct her; in swinging her the compass would stand still for many points and then jump or swing several points; the corrections were applied, and for several years I kept the run of her and was informed that the compass was, as Captain Godfrey expressed it, *as correct as any compass he had used in wooden vessels;* she went to Trinidad, in about latitude 10° north, the captain said that in order to get safely to Boston he was obliged to follow closely on other coasters; he reported that in a head sea when she was pitching heavily his compass swung back and forth very much. Morris explained this to me; she had a long highly magnetized spindle to her steering wheel, which was very far aft; the forward end came within two or three feet of the compass, and he said that every time she pitched and settled aft in a seaway, the poles of this spindle changed, hence the violent oscillations of the needle. Morris illustrated this by removing the fastenings and canting the spindle up and down in imitation of pitching, and I observed a corresponding movement of the needle—he said in his quaint language, "I have a hard nut to crack in this vessel, I must first knock the magnetism out of this long shaft; I am not sure of being able to fix this craft, but I shall try." The result proved that he could do it.

After I had studied Airy, Barlow, and others, I sent their works to Morris; he had read little about local attraction; after reading them, he said, "These gentlemen seem to know much more than I do on magnetism, fixed or induced, and on local attraction, but they fail to find a perfect remedy; they do not pretend to correct an iron ship without a table of errors and for both hemispheres." He also said that if he had had access to these books long before, it would have saved him much anxious thought and much expense in experiments.

He went so far as to say that if he could procure a perfect table of errors in a ship at a distant port, the errors carefully taken by swinging the ship out of the influence of local attraction on the shore, he could formulate corrections and give orders for placing his magnets so as to neutralize the errors; but he said, few men could be trusted to make up the table of errors, hence it would be almost impossible to correct a ship under the circumstances. I inquired in

regard to his process of doing such a work, when he said, "I have a plank at home completely isolated from any local attraction; it is hung on a pivot and revolves freely; this is my ship; having a correct account of the errors, I cause my ship to be beset with precisely the same errors, I correct them and give my orders to the distant ship." As it is many years since he said this, I may be in error as to the premises.

A remarkable incident occurred in regard to a United States ship, I think it was the Hartford; Morris corrected her and she went to the East Indies, some adverse reports came as to the correction of her local attraction; on her return, Morris went on board of her and soon discovered the cause; the small arms which were originally placed in rack at the sides of the ship had been removed amidships not very far from the binnacle, and they had been the cause of the error. Morris was called on to correct one of the ships built at Boston during the rebellion, I think it was the Canandaigua, he found her binnacles as usual placed one on each side and in front of the wheel near which was a round skylight with a high combing, the compasses differed more than usual; I visited her with Morris, he took out of his pocket a compass about four inches in diameter, and applied it to the combing in several places and declared that it was fastened by iron bolts. I saw Mr. Hanscom, the naval constructor, and called his attention to the fact; he said that it was impossible that any iron should be found within five or six feet of the binnacles; Morris pulled out his compass and declared that there were iron fastenings. Hanscom sent for his men and they drifted out one or more of the fastenings composed of *long iron bolts.* Then Morris said that there was iron about the binnacles themselves, and Hanscom said that was out of his line; on examination of the lamps in the binnacles it was found that they were made of tin covered by a coating to give them the appearance of brass; going a little further I went to the store room where the new supplies were kept and found the same dangerous lamps, which by rule should have been of copper.

I have gone somewhat at length into this subject of local attraction in order to show that a man who made no pretensions to science, really accomplished what has never been done before or since to my knowledge, that is, to correct local attraction in iron vessels for both hemispheres without any table of errors. Repeated attempts made by myself to induce the government to adopt Morris's corrections were invariably met by the assertion that they could not do so unless Morris would fully divulge his methods; it was said by the late Admiral Davis, who was in charge of the Bureau of Navigation or Hydrography, that it smacked of empiricism or quackery, and he could not countenance any such uncertainties.

Morris was urged to submit his process to a committee of experts at Cambridge, such as would hear all he had to say under seal of secrecy, and if found expedient they were to be asked to say simply that Morris was no charlatan and ought to be patronized. To this he always said—I give his own words—"As every ship differs in her kind and quantity of local attraction, every one requires special treatment, not only as to the kind of attraction but as to the remedy; I cannot explain to experts in science what I can do, in language that would be at all familiar to them or creditable to me; they would probably so christen my child that I should not know it."

He used to say that local attraction from cast iron must be treated differently from soft malleable metal; he went so far as to say that an iron ship could, at a large expense of labor, be so constructed as to be free from local attraction; in the first place she should be placed heading due north or south, and as every plate, and every bolt, and every rivet, has its north and south pole, that fact must be taken into account in putting all together, so that one piece shall neutralize another. This brings me to one important fact in his operations; this was told me in confidence, but as Morris has gone to the far country where moths and rust and local attraction do not exist, I feel myself absolved from my promise of keeping his secret.

He said, "In Europe they place bars of considerable size and completely charged by magnetism in certain relations to the compass. On going from one hemisphere to the other, the poles of these bars change; not by a sudden jump on the equator, but by degrees as they approach that locality; hence the reversion or the doubling of the errors, as Scoresby said. I make my magnets of small square bars, and by careful manipulation I have a north and south pole for every bar; I reverse these poles and pack them in an air-tight copper case, hence on going into the southern hemisphere my corrections remain intact."

Morris was fully aware that certain changes take place in the magnetism of ships, or iron bars, or plates, or propeller shafts, and that corrections must be renewed from time to time. He said that a shaft revolving rapidly, and with more or less friction and bumping, would be apt to change its character materially: but that the shaft being generally so far from the binnacle that the changes would not affect the compasses; he also attributed the changes found in iron ships to the constant vibration of the machinery, and to the almost constant shocks of the sea.

I have said enough to show how much confidence I had in Morris, who when put into my namesake as mate, from a pilot-boat, was wholly ignorant of local attraction, as most of us were at that time, say about forty years ago; perhaps I have said more than enough to convince you that I am not a scientist in any sense.

I am, very faithfully, your servant,

R. B. Forbes.

NAVAL INSTITUTE, ANNAPOLIS, MD.

November 16, 1881.

Comd. H. B. Robeson, U. S. N., in the Chair.

MACHINE GUNS.

By Lieut. W. W. Kimball, U. S. N.

Machine guns are those engines of war constructed with a view of obtaining by mechanical means, and with a comparatively small personnel for their service, a greater proportional rapidity of discharge of small projectiles than can be produced by other kinds of artillery or by small arms.

The idea of a firearm having many barrels intended to be fired together or in rapid succession was a favorite one among arms makers and arms users in the earliest days of gunpowder-consuming weapons, an idea that resulted in the ribaudequins, orgues, orgels, organ guns and tube guns of the period extending from early in the fourteenth to the middle of the seventeenth century. These weapons were originally of clumsy construction and could not be rapidly discharged, but their employment was continued and their manufacture improved for two hundred years after the discovery of the process of corning gunpowder, probably because in their barrels of small calibre the corned powder could be used, while for field-pieces, owing to the difficulty of withstanding the rupturing strains and controlling the recoil due to granulation, the powder dust was retained. As gun-founding improved and the mobility of field-pieces increased, the use of multi-barrel guns was gradually given up, and for two centuries but little was heard of them as weapons of western nations, although guns of this description were in use in the far East up to a recent date, and as late as 1871 some were found among the armaments of the forts in Korea.

Although there is no record of any practical machine gun having been in use in the field for two hundred years, it is not to be supposed that the idea of such an arm lay entirely dormant for so long a period, and as a matter of fact we find mention of several devices for increasing rapidity of fire. Among them may be mentioned the Puckle gun, patented May 15, 1718. A cut shows this gun to have been a single barrel arm, fitted with revolving chambers six in a "sett." Each "sett" of chambers was fitted with a crank handle, and was removable from a central "screwe whereon ye setts of chambers doe playe off and on." The crank handle served to revolve the "sett" of chambers, bringing each one, in succession, to the firing position at the base of the barrel. As far as I have been able to learn, this application of the revolving principle was the earliest attempt at obtaining that continuity of fire which is to-day one of the chief advantages of modern machine guns. This arm was mounted upon a tripod and fitted with a traversing and elevating lever, in much the same way as are the lighter machine guns of the present time; but unlike them, the form of its projectiles depended upon the religion of the enemy; accordingly it was furnished with a set of cylindrical chambers "for shooting round bullets against Christians," and a set of chambers square in section "for shooting square bullets against Turkes." Again, a century later, we find mention of an eleven barrel machine gun devised by an American for use against the English in the war of 1812.

The impetus given by the Crimean war to the production of highly destructive weapons resulted in the invention of many multi-barrel guns which were submitted to different governments, but none of which were considered worthy of adoption. When the war of the Rebellion turned the attention of American inventors more particularly toward the subject of arms, the machine gun idea again came to the fore, and at the end of the war we find that some twenty-five different machine gun devices had been submitted to the ordnance authorities of the United States.

Three of these guns, the Requa, the Union, and the Gatling, were tried in the field. The Requa gun consisted of twenty-five barrels, each twenty-four inches long, arranged upon a horizontal plane, and held in position by an iron frame mounted upon a light field-carriage. Upon the frame, in rear of the barrels, was fitted a sliding bar worked by two levers (one at each side), by which the cartridges were forced to the rear of the chambers. By a lever under the frame the barrels

could be discharged so as to scatter the balls one hundred and twenty yards in a range of one thousand. It was a volley-firing gun capable, when served by three men, of delivering seven volleys or one hundred and seventy-five rounds per minute. Five of these machines were employed at the siege of Fort Wagner, Morris Island, July 12 to September 7, 1863, and such was the confidence felt in them that up to the forty-second day of the siege they were the only artillery used in advance of the second parallel; they were advanced with the approaches, were depended upon as the main defence against sorties, were used against the enemy's sharpshooters, and, on one occasion—August 23, 1863—took a prominent part in a brisk skirmish. Although these arms were very crude in comparison with the machine guns of the present day—June, 1880—their effectiveness was vouched for by Major Brooks, A. D. C. to General Gilmore, and assistant engineer in charge of the approaches on Wagner, who, in his report to the General, says: "Although the defensive properties of the Requa rifle battery have not been severely tested in the small amount of service above recorded, I feel quite satisfied that it is adapted to the defence of earthworks, particularly in a flat country like this, where the horizontal dispersion afforded by the fire of this piece is more effective than the cone of dispersion of the howitzer."

The Union gun had a single barrel, surmounted by a wide hopper over the breech into which the charges were loosely poured; the function of the breech mechanism when operated by a crank was to bring the charges successively in line with the barrel, load them into the chamber and fire them. This gun was used to some extent in the Peninsular campaign and during the siege of Richmond, but was not considered an effective arm.

The Gatling, essentially in general mechanical principles what it is to-day, was put in the field with General Butler's forces near Richmond, and did effective service in repelling attacks. Among the other machine arms brought into notice during the war of the Rebellion may be mentioned the Billinghurst, of a form like that of the Requa, but without the diverging device; the Vandenburg, a grouped barrelled volley-firing gun, delivering volleys of eighty rounds; the De Brame, a single barrelled gun fitted with six revolving chambers; and the Nugent, in principle very nearly like the De Brame.

Although many of these guns, and particularly the Gatling, the production of which was a long step in advance of the others, possessed many of the requisites of a good machine arm, they all suffered

alike from the lack of an efficient gas-check; and it was not till the perfection of the manufacture of metallic ammunition furnished this essential that the modern machine gun can be said to have existed.

On May 9, 1865, certain improvements upon the Gatling were patented, improvements that rendered it capable of automatically loading, firing, and extracting the empty shells while using metallic ammunition that furnished an efficient gas-check; this solved the problem of producing a practical machine arm. The modern machine gun may be defined as an engine of war capable, through its power of loading, firing, and extracting the fired shells automatically, of producing a very great rapidity of discharge of small projectiles while requiring but a comparatively small personnel for its service.

As soon as the improved Gatling appeared, exhaustive trials were given by the United States Government, and in July, 1866, the gun was tried in competition with the 24-pounder howitzer, as a flank defence piece. The result of this trial was so favorable to the machine gun that it was adopted as a service arm, and on August 24, 1866, an order was given for one hundred guns—fifty of 1″ calibre and fifty of 0.50″ calibre—on condition that they be made at Colt's Armory, Hartford, Conn., an order by which the United States took the lead of the governments of the world in adopting the machine gun as a service weapon. On the eastern side of the Atlantic the merits of machine guns were not appreciated till some time later, and none of them were put in the field in the Austro-Prussian war of 1866. Indeed, no foreign nation except the French seemed to seriously consider the subject before 1869. In 1863, a letter to Dr. Gatling from Major Maldon, of the Committee of Artillery of the French ministry of war, states that "your cannon has created a profound interest"; and, in 1867, a Gatling gun was taken from the Universal Exhibition at Paris and subjected to a series of trials at Versailles, at most of which the emperor Napoleon III. assisted personally.

Soon after, at Meudon, was begun the fabrication of the machine guns known as the French mitrailleuses, and, in 1869, the French had on hand one hundred and ninety of these guns ready to be put in the field for use against the Prussians. In the same year appeared the Agar and Claxton guns in England, and in this year too the Gatling was adopted as a service arm by Russia, that government ordering two hundred and twenty guns from Colt's Armory, which were delivered in due time; while Prussia tried and rejected machine guns of both the Montigny and the Gatling types.

The Franco-Prussian war demonstrated the fact that the machine gun was a practical weapon, under certain circumstances superior to any other. In the affair before Saarbruck it received "the baptism of fire" with the Prince Imperial, and was continually used by the French till the close of the war; often used in positions where good judgment would not have placed it, often left unsupported by infantry, rarely placed in action so that a machine gun battery could defend its own flanks, often exposed to artillery fire unnecessarily, but often, as the slopes of the Mamelon, the glens of Gravelotte, the fields of Beaugency, and the streets of Beaume le Rolande can attest, proving its terrible power as a man-killing machine.

Beside the mitrailleuse, the Gatling and the Claxton were used on the French side. Machine guns were not used by the Prussians except as the captured mitrailleuses were turned upon the enemy, and except two batteries of almost worthless Feldl guns that were attached to the Bavarian corps of Von der Tann. Quickly following the demonstration of its utility in the Franco-Prussian war, the machine gun was generally adopted as a service weapon by the nations of the world. In 1871 England adopted the Gatling, Austro-Hungary the Montigny, Turkey the Gatling, Spain the Gatling; in the year previous Egypt had ordered eighty Gatlings as her machine gun armament. About this time the United States Navy after many trials, the first of which was held in 1863, adopted the Gatling as an arm for use in clearing decks and for boat service, an example soon followed by other navies.

From 1871 to 1874, machine guns were made in three general classes, *heavies*, *lights*, and *mediums*. The heavies were intended to take in a degree the place of shell fire, by supplying great rapidity of fire; the lights were to be used as *hailers*, to supply the equivalent of a concentrated infantry fire, and the mediums were intended to have a greater range than the musket calibre hailers, and still have greater mobility than the heavies. The calibres of these guns ranged from 1″ in the heavies to the musket calibre in use in the lights. In 1874 appeared the Hotchkiss revolving cannon, a gun throwing a shell of 1½ lbs., and after that time the medium guns fell into disuse, the general opinion being that but two kinds of machine guns were necessary: the hailers, using the ordinary musket ammunition, and the revolving cannon or some shell-fire gun. Meantime, in 1872, the Palmcrantz—now known as the Nordenfelt—had appeared in Sweden; the Argentine Republic had adopted the Gatling in 1873, followed in 1874 by China and Japan, and 1875 by Tunis and Siam.

In 1876 the Gardner and Lowell guns were brought out in the United States, and in the same country within the succeeding two years appeared the Taylor and Farwell guns. In 1879 the Hotchkiss revolving cannon, a gun manufactured by its American inventor in France, had been perfected, and was adopted as a service arm by that country and by the United States.

At the present time, June, 1880, the tendency is toward increasing the rapidity of fire of the hailers and the calibre of the machine cannon. The writer has fired from the improved Gatling forty musket cartridges—the charge of a single feed case—at the rate of two thousand five hundred per minute, and has fired one thousand rounds per minute from twenty-five feed cases without great effort. Hotchkiss has proved the practicability of applying his revolving cannon principle to guns throwing four-pound projectiles, capable of penetrating the sides of ordinary merchant steamers at three thousand metres. Dr. Gatling has in hand a single barrel machine cannon for throwing two-pound projectiles; and Nordenfelt has a one inch calibre gun on trial, and proposes to go farther in the direction of increase of calibre. Dr. McLean is manufacturing a machine cannon at New Haven, Conn., the principles of which are not published, but claimed to be such that they can be applied to heavier calibres than have as yet been used in any machine gun.

Since the Franco-Prussian war the machine gun has had a prominent place in all actions of any consequence when it could be obtained. England used the Gatling in her later "wars with peoples who wear not trousers," the Ashantees, the Zulus, and the Afghans; and it was used by the Shah in her affair with the Huascar. The same arm was used by Russia in the Khivan expedition, and by both sides in the Russo-Turkish war.

In the Chileno-Peruvian war at present going on, machine guns have been freely used by both sides, afloat and ashore, the Peruvians using the Gatling and the Gardner, the Chilians the Nordenfelt.

The foregoing brief sketch of the history of the machine gun is necessarily very incomplete, owing to the inability of the writer to obtain satisfactory data.

Place of the Machine Gun in Tactics.

By the military opinion of most nations the machine gun is assigned the place of an auxiliary arm for special service, to be used as occasion may require with artillery, cavalry, or infantry.

English, German, and Swedo-Norwegian authorities pronounce the machine gun absolutely useless for the attack in the field against an enemy provided with good artillery; in France, Russia and Spain the weight of opinion seems to assign to the machine gun the duty of providing a concentrated fire at points in the line where it may be necessary, and where there is not room for infantry during the attack. In the United States there is great diversity of opinion as to the value of the machine gun as a weapon of offence, but it is adapted to move with all three arms of the service.

Since the Russo-Turkish war has demonstrated the value of high angle small arm fire, and since the musket calibre machine gun has been found to be effective against bodies of troops up to three thousand yards, and as machine cannon can deliver an effective small shell fire at still greater ranges, it is not at all apparent that, in the wars of the future, the machine gun will not have a prominent place in the attack in the field; especially if, as is generally conceded, the use of long range small arms has determined that "in case of an army about to attack, it is more than ever desirable to precede the advance of troops by a concentrated fire of artillery."

Against the gun-servants and horses of a field battery, in the open, at ranges above two thousand yards, it would seem that the machine gun fire might be effective, while the gun itself could remain in action unless the field battery were served with the utmost accuracy; for the object of the field gun fire would be the machine gun itself, while that of this latter would be the larger target of the personnel and animals. That this is possible was proved at St. Jean sur Eroc, where the comparatively inefficient French mitrailleuses drove the fine Prussian 12-pounder field gun out of action; if it be possible to use the machine gun against field-pieces in the attack, it would surely be so against masses of infantry or cavalry, and of course against other machine gun batteries.

But from the earliest times of gunpowder-consuming weapons, the effectiveness of the machine gun in the defence has not been questioned. The ribaudequins were used in the defence of fortifications, breaches, bridges and defiles. The Puckle gun, before alluded to, was named "A Defence," and the cut of the gun bears the motto,

"Defending KING GEORGE your COUNTRY and LAWES"
"Ys Defending YOURSELVES and PROTESTANT CAUSE."

It was claimed to be useful in the defence,

"For Bridges, Breaches, Lines and Passes"
"Ships, Boats, Houses, and other Places."

In reporting the results of the trials of July, 1866, that caused the adoption of the Gatling by the United States government, Colonel Baylor says: "In my opinion this arm could be used to advantage in the military service as a flank defence gun, and mounted on a field carriage, to defend a bridge, causeway or ford."

In 1874 Gen. Gilmore's board enumerated as the advantages conceded to the Gatling:

. . . its peculiar power for the defence of intrenched positions and villages; for protecting roads, defiles, and bridges; *for covering the embarkation or debarkation of troops, or the crossing of streams;* for silencing field batteries or batteries of position; for increasing the infantry fire at the critical moment of a battle; *for supporting field batteries and protecting them against cavalry or infantry charges;* for covering the retreat of a repulsed column; and generally the accuracy, continuity, and intensity of its fire, and its economy in men for serving, and animals for transporting it.

In the same year General Barnard's board reports: "Its efficiency in field works, not only for flank but for direct fire, seems unquestionable. This board give it as their opinion that a number of Gatling guns may be effectually used on the parapet of works, as being more accurate in their fire at a distance upon reconnoitering parties, both by land and water, than field artillery, or pieces in position, or even musketry, and they can be served with less exposure. Many of the barbette batteries that have been recommended by this board are isolated and unsupported by permanent works. Some small keeps will probably be built to protect them. The Gatling gun will be found very efficient in these keeps to clear the advanced batteries if attacked by boat or shore parties with a view to spiking the guns, and will sweep the approaches to such batteries. Further, the Gatling gun will prove very serviceable in firing into the embrasures of iron-clad ships that approach within one thousand or twelve hundred yards of a fort. For these various purposes it will be perceived that each fort may use judiciously a number of Gatling guns."

In 1870 Col. Way's committee in England recommended the Gatling:

"To assist in defending such positions as villages, field entrenchments, &c., the committee feel satisfied that the small Gatling would be found invaluable. For the defence of caponnières for covering the approach to bridges or *têtes-de-pont*, for defending a breach, and for employment in advanced trenches or in field-works where economy of space is of the utmost importance, the same sized Gatling would unquestionably be a most effective weapon."

"For naval purposes, the small Gatling would apparently be well adapted for use in the tops of vessels of war, to clear the enemy's decks or open ports; while for gunboats that carry only one heavy gun, and for boat operations, the medium sized Gatling would be most effective in covering the landing of troops or for service up close rivers."

In a second report of the same committee made in 1871, we find that:

"The committee consider that, in addition to its employment on board ships of war, as already recommended, a gun of this calibre would be found excessively useful for the defence of coast batteries *against the attack of boats or for assisting in keeping down the fire of ships, engaging forts at close quarters, or attempting to force a passage by pouring an incessant fire into their ports. Such Gatlings, well served, would effectually put a stop to any attempt at landing*, and would be more reliable at short range than field guns."

"The committee are unanimously of opinion that a proportion of Gatling guns, worked by the artillery and not exceeding the weight recommended in their report of 14. 3. '70—viz., 18 cwt.—should accompany every army in the field, for the specific purposes above detailed, and that they should be kept with the reserves for the express purpose of increasing infantry fire at critical moments, in precisely the same way that guns of position are used for strengthening the fire of the field artillery."

"The committee are decidedly averse to the employment of mitrailleurs for advancing with infantry, or indeed for attacking in any form, except when the enemy is provided with an inferior artillery or no artillery at all."

These extracts from United States and English reports show the attitude of the military opinion toward the machine gun in these countries, an attitude that is not materially different in the other countries of the world, save perhaps in France, where the use of the mitrailleurs for the attack is advocated.

It may then be accepted as the general opinion that, whatever may be the case in the future, the present place of the machine gun in tactics is with the reserves, to be used as a gun of position for strengthening infantry fire at a critical moment, and for holding positions against the charges of infantry or cavalry, be they villages, defiles, fords, causeways, bridges, flanks of a field battery, or what not.

Employment of the Machine Gun in Permanent, Field, and Siege Works.

There seems to be very little difference of opinion as to the use of the machine gun in works; in all countries eminent authorities that have considered the question assign to it the duty of supplying a

rapid fire, continuous, successive, or in volleys according to the type of the arm adopted; in fortresses by direct and flank fire, for repelling attacks from sea or shore, direct or in flank, for driving away reconnoitering parties, for use against sharpshooters, for playing upon the head of a sap, for defending a breach, for ditch defence, and for firing into the ports of attacking ships; in field works, for checking the advance of a line or column of any kind attacking in front, rear or flank, and for use against the enemy's personnel and animals of any arm found within its range; in siege works, for holding the parallels and approaches against sorties, for driving the gun-servants from the enemy's guns by pouring in a destructive fire through the embrasures or over the parapet, and for dislodging sharpshooters.

Naval Uses of the Machine Gun.

In May, 1868, a Board of United States naval officers reported upon the Gatling gun as follows:

"WASHINGTON, D. C., May 30, 1868.

Hon. GIDEON WELLES, *Secretary of the Navy, Washington, D. C.:*

SIR:—The undersigned, composing a board appointed by your order of 14th inst., to examine, test, and report upon the merits of the Gatling gun, as to its value for use in the navy, have the honor to submit the following report:

From the examination made of the gun, and the report of tests hereto appended, the board is of opinion that, as an auxiliary arm for special service, to be used from top-gallant forecastle, poop-deck, and tops of vessels of war, and in boat operations against an enemy, either in passing open land-works or clearing breaches and other proposed places for landing from boats, etc., if opposing infantry and cavalry, it has no known superior.

Its great merit consists in its accuracy within the limits of its range; the certainty and, if need be, rapidity of fire, with the additional merit of only requiring three persons to load, direct, and fire each piece, when suitably mounted, afloat or ashore.

The following detailed report of the trial will, it is believed, fully sustain the opinion of the board.

[Here follows a detailed report of the trial, and a full description of the gun and its ammunition, which is too extended to be inserted in this paper.]

The report proceeds thus:

The mechanism of the gun is simple, and not likely to get out of order; but in such an event it could be repaired on board ship. Spare pieces, as in musket locks, could be a part of the outfit.

Very respectfully, your obedient servants,

(Signed,)
M. SMITH, *Commodore.*
THORNTON A. JENKINS, *Commodore.*
JOHN L. DAVIS, *Commander.*
K. R. BREESE, *Commander.*

During the twelve years that have elapsed since the foregoing report was made, neither the investigations of officers in this and in foreign countries, nor the experiences of service, have developed any new points as to the uses of the naval machine gun; but the necessity of its employment has been accentuated in proportion to the increase of facility of attack by ram and torpedo, and at present its duty may be held to be:

I. In ships: mounted about decks, on the rail or in tops, to deliver a murderous fire upon the enemy's decks, or through his ports during the supreme moment of the struggle for a close; to clear the decks of boarders; to provide a defence against boat attacks of all kinds, boarding or torpedo; to sweep the parapets and embrasures when running past shore works of any kind, and in operations close in shore to furnish an effective fire against exposed men and animals.

II. In boats: to clear a proposed landing place of the enemy's infantry or cavalry, whether it be an open beach, a river bank, or the approaches of a silenced fort; to sweep off the enemy's boats' crews in interior waters; to defend the boats against a surprise party after the landing is effected, and to cover the re-embarkation.

III. On shore: with the naval brigade or with the army, to be useful in all ways that the shore machine gun can be, from quelling a mob to assisting in the defence of a fortress.

Organization.

In the United States the machine gun has no organization proper; it is considered an auxiliary weapon, and is intended to serve with any arm of the service in such proportion as the occasion may require. The guns for service with the cavalry are either tripod guns, to be carried on pack animals, or are mounted upon *cavalry carts*, light carriages carrying the gun and two small ammunition boxes and drawn by a shaft horse with a driver's horse in traces alongside.

The French and Spanish have batteries composed of six guns, the Bavarians of four, and the Russians of eight. Col. Wray's committee proposed that twelve Gatlings should compose a battery, while the Swedo-Norwegian committee considered that it should consist of four pieces.

Thus it will be seen that there is great diversity of opinion as regards organization, that, in fact, the question is an undecided one among military men. To the writer, who has had a little experience with American cavalry, it has occurred that four-piece machine

gun batteries may be expected to appear, the guns of the light tripod mount type, carried on pack horses, each gun-servant mounted and leading an ammunition pack animal. Such a battery could move with cavalry, could attack in the open, could quickly take or make cover, and, if doing coast patrol duty, would be especially annoying to a force making a descent upon an otherwise undefended coast. It would seem that four should be the number of pieces, for the reason that that number would allow great mobility, while it is the smallest that would render such a battery capable of checking advancing lines or masses, and at the same time of defending its own flanks. In the naval brigade the machine gun is made a part of the field artillery organization.

Supply of Ammunition.

The question of the supply of ammunition for the machine gun in the field has never been satisfactorily settled, for the reason that the limit of its transport is so far within the consuming capacity of the gun. Some authorities state that the gun should never move with a less supply than ten thousand rounds, but the way of transporting it without unduly hampering the gun and destroying its mobility has not been pointed out. Apart from the great consumption of ammunition, most machine guns require it to be stowed in some sort of a feeding device in order to get the greatest rapidity, a device that invariably renders the weight greater and the bulk more cumbersome. The ordinary limber for the shore Gatling gun takes but two thousand rounds of ammunition, a supply that could be exhausted in two minutes of rapid firing; and in general, the field supply for machine guns is very inadequate. The United States navy Gatling on shore has but three thousand rounds to draw on from the pouches of its twenty gun-servants and from its ammunition boxes; and even if the limber be used, with its fifteen hundred rounds in feed cases and two thousand in bulk, the total supply is only six thousand five hundred rounds, while the mobility of the piece is very greatly injured.

For the supposititious mounted coast patrol battery mentioned above, there would be necessary ten ammunition pack animals per piece to furnish an approximately adequate supply of ammunition, and at the same time enable the battery to move at a run across rough country, for the feeding devices are so cumbersome that not more than one thousand rounds can be packed upon a single animal

that is expected to leap obstructions. The battery with its eighty-eight horses and forty-four men would offer a large target for the fire of a force descending upon the coast patrolled by it.

When the machine gun is mounted in field, permanent or siege works, aboard ship or in boats, the question of ammunition supply is not a serious one.

Concluding Observations.

The experiences of the Franco-German war seem to show that the machine gun has particularly to dread artillery fire at long range, and successive charges of skirmishers that close in upon its flanks as the ammunition supply becomes exhausted; and it would seem that the questions of holding positions against artillery fire, and of expending the ammunition upon advancing lines or reserving it for attacks in flank, are debatable, fully worthy of the consideration of officers in command of machine gun batteries. It is evident at anything like long range the fire should be very carefully made and comparatively slow; that the feed devices should be kept full for critical moments by reloading them from supplies of ammunition in bulk, if such there be, and that if the battery have no infantry flank support, the flanking guns must be ready to repel an attack even if their effectiveness in work in front be decreased. In a mixed naval battery the machine guns must form the support for the artillery to a great extent, and leave the infantry force unhampered by that duty.

In order that the gun may work up to its full effectiveness, the machine gunners must have a very considerable degree of intelligence, and the utmost steadiness; compared with infantrymen armed with single loading shoulder pieces, they must be as clever mechanics are to common laborers—they must be capable of working with a killing machine instead of a killing tool; they must understand the complicated mechanism of the gun and know its requirements; they must be able to comprehend that retreating from an untenable position to take up a more favorable one is not running away from the fight; they must be habituated to the feel of the crank till the slightest derangement of the mechanism becomes apparent to the touch; they must know how best to apply their power in working the firing device, be it crank or lever; and, above all, they must have that coolness in danger that will enable them to quickly clear a jam in the working parts or replace a disabled lock, and to refrain from rapid firing at improper times. Beside these requirements for the

field, the naval machine gunner must have forethought and quickness; forethought to enable him to have his gun ready for the critical moment, and quickness to seize the few seconds allowed him for work against an approaching torpedo boat, or through the opening ports of a ship. We of the navy are in duty bound to see that our machine gunners possess these requirements as far as they may be attainable through drill, discipline and instruction.

Six Typical Machine Guns classified according to Manner of Delivering Fire.

- Machine guns that deliver fire—
  - Continuously— / Successively—
    - By mechanism operated by crank—
      - 1. From single fixed barrel..... Lowell.
      - 2. From fixed barrels arranged in pairs.......... Gardner.
      - 3. From revolving barrels grouped around axis of system.......... Gatling. Hotchkiss.
  - Successively and in volleys—
    - By mechanism operated by lever—
      - 1. From fixed barrels arranged in horizontal plane............ Nordenfelt.
      - 2. From fixed barrels grouped around axis of system.......... Montigny.

Descriptions of a few Machine Guns.

The Gatling.

The Gatling gun consists of a number of very simple breech-loading rifled barrels grouped around and revolving about a shaft to which they are parallel. These barrels are loaded and fired while revolving, the empty cartridge shells being ejected in continuous succession. Each barrel is fired only once in a revolution, but as many shots are delivered during that time as there are barrels, so that the ten barrel Gatling gun fires ten times in one revolution of the group of barrels. The action of each part is therefore deliberate, while collectively the discharges are frequent. The working of the gun is simple. One man places one end of a feed-case full of cartridges into a hopper at the top of the gun, while another man turns a crank by which the gun is revolved. As soon as the supply of cartridges

in one feed-case is exhausted, another case may be substituted without interrupting the revolution or the succession of discharges. The usual number of barrels composing the gun is ten. The bore of each barrel extends through from end to end, and the breech is chambered to receive a flanged centre fire metallic case cartridge. The breech ends of all the barrels are firmly screwed into a disk or rear barrel plate, which is fastened to the shaft, and the muzzles pass through another similar disk, called *front barrel plate*, on the same shaft. The shaft is considerably longer than the barrels, and projects beyond the muzzles, and extends backward for some distance behind the breeches of the barrels. Directly behind the open barrels a cylinder of metal, called a *carrier block*, is fastened to a shaft, and in the exterior surface of this carrier block ten semi-cylindrical channels are cut, which form trough-life extensions of the cartridge chambers of the barrels to the rear, and are designed to receive and guide the cartridges while they are thrust into the barrels, and to guide the empty cases while they are withdrawn. Behind the *carrier block* the shaft carries another cylinder, called the *lock cylinder*, in which ten guide grooves are formed, which are parallel to the barrels, and in which slide ten long breech plugs or *locks*, by which the cartridges are thrust into the barrels, and which close the barrels and resist the reaction of the charges when they are fired. Each plug or lock contains a spiral mainspring acting on a firing pin, by which the charge is fired, so that the plug performs all the functions of a gun-lock, as well as of a breech plug. The shaft, to which the group of barrels and both the carrier block and the lock cylinder are rigidly attached, is free to turn on its axis, the front end being journaled in the front part of the frame and the rear end in a diaphragm in the *breech casing.* The breech casing extends to the rear far enough to contain not only the *diaphragm* through which the main shaft is journaled, but also form in the rear of the diaphragm a cover for the gearing by which the shaft is revolved. This mechanism or gearing consists simply of a toothed wheel fastened to the shaft and worked by an endless screw on a small axle which passes transversely through the case at right angles to the shaft, and is furnished outside the case with a hand crank. A cascable plate closes the end of the case. Each lock carries a hooked *extractor*, which snaps over and engages the cartridge flange when the lock is pushed forward, and which, when the lock retreats, withdraws and ejects the empty case. The *cartridge carrier block* is covered above the frame by a semi-cylindrical

shell, which is provided at the top with an opening of suitable size and shape to permit a single cartridge to fall through it into one of the channels of the carrier block, which it overlies. There is a trough extending upward from this opening and forming a *hopper*, in which a straight feed case can be placed in a vertical position, containing a number of cartridges lying lengthwise across the case, one above another. Beneath the *carrier block* everything is open so as to allow the cartridges or shells which are withdrawn by the extractors from the barrels to fall to the ground. Within the cylindrical breech case attached to the frame a heavy ring not quite the length of the lock cylinder is fastened to the case and diaphragm, which nearly fills the space between the inside of the case and the cylinder. Portions of the inside of this ring are so cut away as to leave a truncated, wedge shaped, annular or spiral *cam* projecting from the inner surface of the ring, having two helicoidal edges inclined to each other and united by a short, flat plane. Against these edges the rear ends of the locks continually bear, there being room enough for the locks to lie loosely within the parts of the ring which are cut away. The apex of the wedge-shaped cam points to the barrels. Each lock is held back against the cam by a lug or horn projecting laterally from the end of the lock and entering a groove formed at the base of the cam, in the thin part of the ring.

Straight Feed Cases.—The cases which contain the cartridges, and which are applied to the hopper when it is desired to feed the gun, are long narrow boxes of sheet tin reinforced by gun metal, open only at the lower ends. The cross section of the case is trapezoidal, the edge next to which the heads lie being wider than the cartridge heads, while that which receives the points of the balls is of the width of the ball. This form enables all the cartridges in the case to assume a horizontal position, because the heads of the contiguous cartridges have room to roll over slightly, so as to lie partly alongside of each other, while the ball ends are kept vertically over each other. Above the cartridges in the case is a weight which can be moved up and down by a thumb piece. By the action of the hand pressing on the thumb piece any desired pressure, regulating the rapidity of feed, can be given to the cartridges. Each straight feed case contains forty cartridges.

The Gatling is at the present time, June, 1880, the favorite machine gun of the world; more generally adopted as a service weapon, better proved by service, and more highly recommended by eminent military authorities than any other.

It has the only truly revolving system, and provides continuity of fire with a rapidity double that of any other gun. Taking into consideration the date of its invention, the late improvements in its construction, the excellence of its manufacture and the ability of the people who have it in charge to make required improvements, there seem to be good grounds for the assertion of its ardent admirers that as a musket calibre gun "it was the first, is the last, and always will be the best"; certainly good grounds for all the assertion except the part comprehending futurity. It is the only continuously firing gun that gives an appreciable time for a "hang fire" cartridge to explode while holding it firmly in the chamber of the barrel.

The French Mitrailleuse.

The French mitrailleuse is composed of twenty-five barrels, fixed in five layers, one above the other; the whole surrounded with a bronze casing, so as to give it the appearance of a field gun.

This casing is prolonged to the rear, when it forms a box open at the top, in which the loading apparatus is moved backwards and forwards by means of a screw placed in prolongation of the medial line.

The loading apparatus is composed of two parts, viz., 1st, a cartridge plate, with twenty-five holes corresponding to the barrels, and in which the cartridges are placed; 2d, a firing arrangement which contains twenty-five locks, each composed of a piston and a spiral spring.

In loading, the cartridge plate and the firing arrangement are carried forward by the screw, during which operation the cartridges are partly pushed into the barrels; the pistons being brought up by a closing disc, which also produces the cocking of the piece.

This closing disc has twenty-five holes, and can, by means of a lever handle fixed to the right side of the piece, be drawn sufficiently to the side to allow the pistons to pass though the corresponding holes, and so to ignite the cartridges. The number of rounds which can be habitually fired with this mitrailleuse is only one hundred to one hundred and fifty per minute.

Its service is laborious, and it easily gets out of order. It is also possible for the cartridges to be fired before the breech arrangement is properly closed—a very serious defect.

The Montigny Gun.

This gun resembles the French in general principles, but differs from it in the following details:

It is furnished with thirty-seven barrels instead of twenty-five, and the screw by means of which the loading apparatus is brought into play is replaced by a lever moving in the same vertical plane as the medial line.

The handle which gives rotation to the closing disc of the "pistons and strikers" is also replaced by a long lever, which moves on the right side of the piece, parallel to the preceding one.

This mitrailleuse has fired as many as three hundred and fifty to four hundred rounds per minute. Under ordinary circumstances, however, this rate cannot be expected. We may take its normal rate of fire as about two hundred rounds per minute.

The construction appears simple, but it is really somewhat complicated, the mechanism being composed of a number of parts. Notwithstanding these defects, it is solid, and not easily liable to get out of order.

The Palmcrantz Gun.

A Swedish invention brought out in 1871 by the person whose name it bears.

The system consists of a rectangular frame of cast iron, the sides of which are connected by three plates or transoms. The frame is furnished with trunnions, and is capable also of lateral movement on a pivot.

The ten barrels are placed side by side in a frame, their muzzle ends passing through the front transom, while the breech ends are screwed into the middle transom.

Between this middle transom and the rear one there is a parallelopiped box, containing the mechanism, which is capable of movement backwards or forwards.

In it are ten pistons or plungers, corresponding to the barrels. These are of steel, pierced with a channel in which a needle or striker moves freely, and are furnished with an extractor on the right side.

Behind each plunger is a cylindrical cock of steel, with a projecting tenon underneath; and behind the cock, again, a strong spiral spring.

The "carrier," or feeder, is a plate of copper, having ten longitudinal holes for the cartridge cases to drop through when extracted, and a similar number of strips on which to carry the cartridges when loading. It is capable of a slight lateral motion, which is given by a forked arm pivoting freely on the motive axis, and moved to the right or left by a projection on the under surface of the lock.

The carrier is supplied with cartridges by a magazine in the shape of a parallelopiped box having ten vertical divisions, each of which holds twenty-five cartridges. Grooves are cut in the sides of the divisions at the rear, for the projecting part of the base of the cartridge to slide in. The magazine has a movable bottom, with ten rectangular holes, through which the cartridges drop on to the carrier ten at a time.

The carriage is of iron, consisting of two brackets, on the upper part of which is secured a horizontal plate of iron in which the pivot of the gun frame works.

The Feldl Gun

was the invention of a citizen of Augsburg, from whom it takes its name. It appeared in 1869, and was put in the field by the Bavarians in 1870, in two batteries of four guns each. It consisted of four parallel barrels rifled upon the Werder system, revolving with the breech mechanism by the action of a crank. An oscillating fixture spread the fire over an arc of 28°. The writer has been unable to obtain a description of the gun in detail, but from the date of its appearance and the main features of the system it would seem that it is an inefficient revolving system, continuous fire gun; in short, a failure at an attempt to imitate the Gatling.

The Agar Gun.

An English invention, appearing about 1869. It has a single stationary barrel screwed into a stationary breech-piece. The function of the breech mechanism, operated by a crank or lever, is to receive the charges in succession from the feed device, load them into the chamber, fire them, and extract the empty shells. This gun has never seen service.

The Claxton Gun.

Invented in 1868 by Colonel Claxton, an English officer, after he had seen the Gatling. It consists of 8, 10, or 20 barrels, to be fired in pairs by the action of a reciprocating motion, or rocking lever. A few of these guns saw service with the army of General Faidherbe in the Franco-German war, but the record they made was not greatly to their credit.

The Nobel Gun (so called).

This is a modification of the old Gatling: it is in fact the Gatling with the centre feed and rear crank as applied by Mr. Nobel, the

manufacturer of the Gatling in Russia, and as now used by the Gatling Gun Company.

The Farwell Gun.

Appeared in 1876. It consists of ten barrels held by a frame in a horizontal plane, the whole capable of a lateral motion imparted by the action of an oscillator. Its back mechanism is operated by a crank. The cartridges are received, from magazines somewhat similar to those of the Palmcrantz, by the double-jawed receivers, which close as the locks push the cartridges into the chambers and open as the extractor draws out the empty shell, allowing it to fall through them. It is a continuous-fire gun, very complicated in design, and has never, within the writer's knowledge, successfully passed the ordeal of trial.

The Lowell Gun.

Appeared in 1876. It is the invention of Mr. Farrington, of the United States Cartridge Company, Lowell, Mass., and is of the single barrel type. The gun, as made, has four barrels, in order to change a heated for a cool one; an operation that is performed by revolving the heated one out of the way and bringing the cool barrel into the firing position by hand. A few of the guns have been acquired for trial in the United States army and navy.

The system is composed of two distinct parts, viz. the barrels, with their disks and trunnions, and the frame and breech, containing the mechanism. The barrels—generally four, although a greater number may be used—are mounted between two supporting disks, arranged to revolve in rings. The ring at center of barrels is provided with trunnions, which work in the frame connecting the barrels with breech mechanism. The rear ring and inclosed disk, when the barrels are in position, lock with the frame. By this arrangement of the barrels they can be disconnected from the breech and tilted up, allowing them to be readily inspected or cleaned; also facilitating the extraction of any obstruction. One of the peculiar features of this gun is that the firing is confined to one barrel at a time, requiring but one lock. This barrel is used until heated, disabled, or clogged, when it is rotated aside by a simple lever movement and another brought into place, and this can be done quickly and without shutting off the feed. The upper barrel being the one fired,

it is always in sight of the operator, and any damage to it, such as bulging or bursting, can be readily detected and its use in subsequent firings avoided.

The breech mechanism is contained in a housing of brass, the lower half of which is securely bolted to the connecting frame, the cover or upper half being secured to it by hinges on the left side and on the right by catches when closed. The cover is in two parts, so that the whole breech mechanism can be exposed, or only that part of it which receives the cartridges from the feeding-tube. The advantage of this arrangement is apparent. In about fifteen seconds the cover can be thrown open, and the working parts, which occupy but little space and are exceedingly simple and strong, can be removed and replaced without tools by any man of ordinary capacity. The principal parts of the breech mechanism are, the crank-shaft and worm for rotating feed or carrier rolls; the "lock-plunger" with its firing-pin, firing-pin spring, and two extractors; two carrier-rolls and shafts with gearing, and the feeding-tube. The crank works from the rear, and for purposes of drill or exercise the machinery can be reversed without change. The lock-plunger has two strong extractors operating positively and not depending upon springs. These extractors grasp the cartridge-shell on opposite sides and remain locked until the shell is fully withdrawn. The firing-pin has an elongation pointing downward which, as the worm rotates, is forced back by a cam on the worm, compressing the spring. The moment the firing-pin is released, it strikes the primer of cartridge and discharge takes place. The carrier-rolls are simply two cogged wheels, revolving in opposite directions, and so arranged as to receive between their teeth the cartridges delivered from the feeding tube; the rolls carry the cartridges between plunger and chamber of barrel, receive the fired shell, and by further movement of crank, force the shells to fall to the ground. One entire revolution of the crank fires and extracts three cartridges. The feeding tube consists of an upright brass tube, firmly set in a socket directly over the carrier-rolls; it can be removed, if necessary, by loosening a set screw at its lower end. This tube has a slot on its forward side, extending its whole length, of a width slightly greater than the diameter of the cartridge. It is also slotted on its interior to receive the head of the cartridge, being slightly trumpet-shaped at its top to facilitate the introduction of the cartridge. It will hold about thirty cartridges. In the socket which holds the feeder is a stop with a milled head, normally held back by

a spiral spring that allows the cartridge to fall. Should it be desirable to stop the feed, the operator pushes in this "stop," turning it slightly to the left, it being held in that position by a small pin entering a slot. There are also provided for service with the gun feed-cases of tin, holding seventeen cartridges each; the cases are made by simply turning a piece of tin about one inch wide so as to hold the heads of the cartridges by their flange; pieces of steel bent over the ends of the case and soldered to it hold the cartridges in place.

By placing the case in "feeder" and pressing on the top cartridge, the steel spring is forced back, and cartridges drop into place.

The traversing motion is given by means of an eccentric, the shaft of which is connected by a worm and gearing to the crank-shaft. The eccentric is so arranged that the amount of traverse can be regulated from 0 in degrees upward by the person operating the gun, who can spread or reduce the space covered by his fire according as the object approaches or recedes, increases or diminishes its front, and this without stopping the fire.

The Taylor Gun.

This invention of Mr. J. P. Taylor, of Tennessee, appeared in its present form in May, 1878, when it was given a trial by the United States army ordnance authorities, a trial which resulted in the favorable mention of the gun, but which at the same time showed its weakness in feeding as compared with the better perfected machine guns.

It consists of five barrels arranged in a horizontal plane, and together with the breech casing, held in place by an iron frame. The feeding device consists of five flanged ways, one for each barrel, each somewhat similar to the single feed tube of the Lowell gun. The ammunition is packed in square straw-board boxes, containing twenty-five cartridges each, and is fed by the flanged ways directly from the packing boxes. The function of the crank operated breech mechanism is to receive the charges from the flanged ways by opening feed-valves, to load them into the chambers in succession and fire them.

It is a continuous fire gun, and is fitted with the usual oscillator.

The Nordenfelt Gun.

This gun is the Palmcrantz modified and improved, at present manufactured by Mr. Nordenfelt, in England. In that country and

generally on the eastern side of the Atlantic it is held in high favor, both as a musket calibre *hailer* and as a machine cannon with barrels of 1″ and 1.5″ calibre throwing shell and solid steel projectiles.

In using the heavier calibre guns two disastrous accidents have occurred on board of British ships, but it is now claimed by Mr. Nordenfelt that the the defects that rendered these accidents possible have been eliminated from the system.

The Gardner Gun

Appeared in 1875, and was given a trial at the Washington Navy Yard in the latter part of 1876, when it showed many excellences and a few defects; these last, mostly in connection with the extraction, have since been remedied by the present owners of the gun, Messrs. Pratt & Whitney, of Hartford, Conn. A board of United States army ordnance officers convened to test it reported, on March 17, 1880, as follows:

The Gardner gun consists of two breech-loading rifled barrels, calibre .45, chambered for the service cartridge, placed horizontally and parallel, 1.4 inches apart, which with the working mechanism are enclosed in brass casing. By one complete turn of the hand-crank both barrels are loaded, fired, and the shells ejected. The barrels are held in position by rear and front barrel rings pinned to the case. The casing extends sufficiently from the rear barrel ring to contain the lock mechanism, together with the *driving crank* and *safety stop*. A swinging cover, hinged immediately over the rear barrel ring, gives easy access to all working parts of the gun in case of defective cartridges, derangement of locks, or other accident. The cover when closed is secured in position by a few turns of the cascable, which for that purpose has a screw-thread cut on its neck or stem entering the rear of the case. The hand-crank that operates the gun is pinned fast to the *main crank*, which is supported by journal boxes. The boxes are locked into the rear case, and serve as a protection to the swinging cover from side thrusts. The body of the *main crank* is circular, having journals or crank-pins for operating the locks diametrically opposite each other—the firing being alternate—and eccentric enough to give the required motion to the locks as they are moved forward and back, driving in cartridges and withdrawing shells. The outer portion of the crank-pins or journals are flattened to the circle of the periphery of the main crank for the purpose of holding the lock stationary while firing, about one-fifth part of the revolution of hand-crank, allowing time for *hang-fires*. The lock in form resembles the letter **U**, having an extension from its side, which contains the *firing-pin*, *main* (spiral) *sector* or *spring-compressor*, *sector sleeve*, *extractor*, and *lock-head*. The **U** part of the lock that works under and around the crank-pin is curved at the inner front to correspond with the outer circle of the crank, the office of the curved front being to hold the lock in position for firing. The circular firing-pin is flattened a portion

of its length near the front end, to allow it to pass under the extractor, by which it is held in position. It extends from the head of the lock through the main spring and sector sleeve, terminating in a flange or head for locking into the sear. The *sear*, having the form of a bell-crank, pivoted in the center to the lock, holds the firing-pin securely and prevents its forward motion until it is released from its hold by the action of the crank-journal when the lock is in its extreme forward position.

The sector or spring-compressor, hinged in a recess of the lock and engaging by means of gear-teeth with the sector sleeve, has its arm forced against the safety-stop as the main crank advances, thus compressing, through the medium of the sector-sleeve, the main spring and holding it tense until released by action of the sear.

The lock-heads serve as breech-plugs, and receive the recoil when the cartridges are fired. Each lock carries a *hook extractor*, which rides over and catches the flange of the cartridge when the lock is forced forward, and when the lock retreats withdraws the empty shell until it comes within reach of the ejector, by which it is positively thrown out. The shell starters have a positive movement in connection with the lock-head. Should the cartridge be driven by the extractor into the barrel to its head (as is the case when the gun is worked rapidly) before the lock is in firing position, it is forced from the chamber by the shell-starter as the lock advances and is held long enough for the extractor to engage with the head, when the lock, extractor, and cartridge are driven home together.

The *ejectors*, hinged to the case, are driven by projections on the sides of the locks which give them lateral movements to eject the empty shells, or full cartridges in case of miss-fires. They also serve as stops to prevent the cartridges from falling through the perforated plate as they are forced down through the feed valve.

The perforated plate extending across the rear case, to which it is fastened by a pin, has two parallel semicircular grooves, which are enlarged *extensions* of the chambers in the barrels. From the back part of the groove slots large enough to pass freely the cartridge (being wider at the rear behind the ejector than at the front) are cut downward through the plate. When the retractor has drawn the shell back nearly to the extent of the throw of the crank the ejector forces the shell through the slot, and is then in position to receive another cartridge from the feed plate or valve. The feed valve, attached to the swinging cover, has a reciprocating motion across the perforated plate. It has two angular openings of the size and shape of the outline of the cartridge, with centers equidistant with centers of the barrels. After a cartridge has dropped one-half its diameter into the valve it is forced by the action of the atter into its true position and held positively against the *cartridge support*. When the valve is again moved back the cartridge is forced downward into the perforated plate and the column of cartridges is cut off in the swinging-cover feed ways, which are extensions of the *feed guide* that is located above and in line with the perforated plate.

The feed valve is driven by the *feed plate* lever. This also is attached to the swinging cover and is operated by the locks, using about one-eighth the stroke

of the crank in its forward motion, thereby giving the valve time to hold both cartridge and shell down in position as they move in and out from the barrel. The *feed guide* is a simple plate, having two parallel T-grooves extending from end to end, their centers equidistant with the centers of the barrels. The upper end of the guide has a trumpet-shaped mouth, to facilitate the entrance of the cartridge heads. The lower end is provided with a cartridge stop, which lifts all cartridges contained in the guide when it is taken out from the swinging cover by which it is supported. The guide is held fast in firing position by a spring catch. It can be quicky released by drawing back the spring catch by pressure on its exposed arm. In placing the guide in position the spring catch becomes self-acting. These operations require but one hand, leaving the other free to place the safety-stop arm in position. The safety stop is an oblong block having an angular face, against which the arm of the sector in the lock may engage when the locks are moved forward by the crank. It is held in position by two links, which are moved by an arm that is pinned fast to a shaft passing through the rear case, to the outer end of which is pinned the stop-arm. This arm is constructed in the form of a hand-crank, having a stop spindle placed in its handle, behind the shoulder of which is placed a spiral spring that forces the spindle out from the arm into the stop-holes, two in number, in the rear case. When the stop spindle is in the upper hole the *arm is in line* with barrels, the safety stop is thrown within reach of the sector arm, by which the main springs are compressed, and the gun is in firing position. When the spindle is in the lower hole the stop is carried forward out of the way of the sector arm, and in no case can the springs be compressed while the safety arm is down.

The cartridges are contained in perforated wooden blocks (holding twenty each), channeled on the sides for receiving the fitted tin covers in the manner adapted to the Gardner gun. The cartridges thus arranged are simply and readily conveyed through the feed guider to the gun, and as the block is emptied before the cartridges previously inserted are expended a continuous fire can be sustained.

In the service of the gun three men are required; one at the lever and turning the crank, one inserting and withdrawing the cartridge blocks, the other in passing cartridges, properly fitted in their blocks.

Results of Firing.

Twenty cartridges, fired for the purpose, gave an average initial velocity of 1280 feet. A test for rapidity of fire gave an average of 357 per minute.

The target firing at targets of spruce boards, 11x52 feet, resulted as follows:

At 200 yards, 98.20 per cent. of hits.
At 500 yards, 92.20 per cent. of hits.
At 1000 yards, 52 per cent. of hits.

Recommendation.

The trials of this gun at Sandy Hook having shown it to be one of simple construction, easily manipulated, and of sure action (though of less rapidi y of fire than any other machine guns heretofore tested by the Board), and in view

of the fact that its cost, for a machine gun, will be comparatively light, the Board would recommend the purchase by the Department of a limited number for actual trial in service, as compared to other machine guns now in the hands of troops.

The Hotchkiss Revolving Cannon.

The invention of Mr. B. B. Hotchkiss, an American located in Paris, appeared in 1874. Since that time it has been modified and improved, and is to-day the favorite machine cannon of the United States and of France. It has been adopted by the latter country as a service arm afloat and ashore, and by the Bureau of United States Naval Ordnance as a part of the machine gun armament of the navy. As the gun first appeared it was adapted to fire 1.5 lb. projectiles, but within the past year the system has been found capable of being applied to heavier calibres, and the inventor has demonstrated the practicability of a 4-pounder machine cannon, good against ordinary merchant steamers at three thousand metres. Owing to its lack of preponderance and recoil the gun can, by means of a shoulder-piece lever, be kept bearing upon a moving object, and is therefore especially adapted to work against torpedo boats, while at the same time fulfilling the other duties of the naval machine gun.

THE GENERAL SYSTEM.

The Hotchkiss revolving cannon cannot be classed with mitrailleuses in the ordinary sense of the latter term, as explosive shells are fired with the former, and it has a range equal to that of a field-artillery.

The system of this gun may be explained as follows:

Five barrels, grouped around a common axis, are revolved in front of a solid breech-block, which has in one part an opening to introduce the cartridges, and another opening through which to extract the empty shells, while the cartridges are fired after being revolved and while motionless in front of the solid portion of the breech.

The exterior aspect of this revolving cannon resembles the Gatling mitrailleuse, it being, on the other hand, entirely different in its interior mechanism.

The system is composed of two distinct parts, viz. the barrels with their disks and shaft, and the frame and breech containing the mechanism.

The five barrels, made of the finest oil-tempered cast steel, are mounted around a common axis, between two disks, on a central

shaft. The series of barrels are in this way placed in a rectangular frame, which is attached to the breech, the near end of the shaft penetrating the same to receive the rotary motion from the driving-gear.

The breech itself is composed of a solid cast-iron breech-block, weighing about 386 pounds. This absorbs the greater part of the recoil. It has a door at the rear end, which can be easily opened, so that the mechanism is freely accessible, and can, if necessary, be dismounted and put back into its place in a few minutes, without the aid of any special tools.

A peculiar feature of this gun consists in the barrels remaining *still* during the discharge, so that there is no movement of any kind to impede the accuracy of the fire. This stop or lost motion is obtained by the shape of the driving-worm, which is so constructed that the inclined driving-thread only covers half its circumference, the other half of the thread being straight. The effect of this is that the barrels only revolve during half a revolution of the worm, and stand still during the other half revolution. The combination of the mechanism is so arranged that the loading, firing, and extracting take place during this pause. This feature is of great importance for the accuracy of fire and the durability of the system.

The worm-shaft projects through the breech on the right side, and has a crank with which the whole system is moved; on the left side of the worm-shaft a small crank is attached, by which the loading and extraction of the cartridge-shells is effected in the following manner:

On the interior face of the left side of the breech a cog-wheel is mounted, with two horizontal racks, the one being placed above the other under this cog-wheel, and parallel to the axis of the barrels, so that in moving one of these racks the other is moved by the cog-wheel in the opposite direction. Part of the lower rack forms a vertical slot, in which the small crank on the left side of the worm-shaft works. The rotation of the latter consequently gives an alternating and opposite movement to the two racks, so that while the one is going forward the other moves back, and reciprocally.

The under rack forms the extractor; the upper one moves a piston which drives the cartridge into the barrels, the cartridge being placed before the piston, in the trough in which it moves; and during the time the barrels are motionless it is introduced into the one standing before the trough. The cartridge is not "driven home" entirely,

but its head is in view of an inclined plane, cut into the metal of the breech, on which it slides when it is moved by the rotation of the barrels. This completes the introduction of the cartridge into its chamber. The piston itself is a simple cylinder connected with the rack, and running in a slot in the conducting-trough.

When the racks are in their extreme positions they remain still a moment. This stop is obtained by giving the slot in its centre part a circular shape concentrically to the shaft of the crank. This is necessary, because at the moment of the barrels arriving at the end of their course the head of the cartridge-case becomes engaged in the hooks of the extractor, which would not be possible if it were in motion at the time.

The extractor is a large double hook at the end of the bottom rack; it is very solid, and its proper working is certain under all circumstances.

After the cartridge is extracted from the barrel it strikes against an ejector, which pushes it out of the extractor, and it falls to the ground through an opening in the under part of the breech. The firing-pin has an elongation, pointing downward, which, by the operation of a spring, is pressed against a cam on the worm, and as the worm rotates, the cam drives the firing-pin back and compresses the spring. The moment the firing-pin becomes liberated, it strikes the primer of the cartridge and the discharge takes place.

To obviate the difficulties which exist in other systems, when the cartridges are piled one upon the other, the opening of the introduction-trough is closed by a little door, which goes down by the weight of the cartridges, the first of which drops into the trough, and the piston, in moving forward, raises the door and allows no more cartridges to enter until the proper time.

All parts of the mechanism are very strong and durable, and hardly exceed in number those of an ordinary small-arm, there being, besides the group of barrels, thirteen parts, viz:

1, 2. The breech-block, with its door for closing the rear end.

3, 4, 5. The crank-shaft, with its worm for moving the barrels, and small crank for working the loader and extractor.

6. The crank.

7, 8. The firing-pin and spiral spring.

9. The extractor.

10, 11. The loading-piston and rack for moving it.

12. The cog-wheel for transmitting the movement of the extractor to the loading piston.

13. The door for regulating the feed of cartridges.

The Gatling Machine Cannon.

This invention of Dr. Gatling has not been completely worked out. It consists of a single barrel of 1.45″ calibre, firmly screwed into a solid gun-metal breech casing containing the mechanism that receives the charges from the feeding device, loads and fires.

At present, June, 1880, the weight of evidence goes to show that the Gatling musket calibre gun leads the van among the *hailers*, with the Gardner and the Nordenfelt close in its wake. Among machine cannon the Hotchkiss leads, with the Nordenfelt taking the second place.

HARTFORD, CONN., June 1, 1880.

Since this paper was prepared in June, 1880, the American Improved Gardner, manufactured by the Pratt and Whitney Company, of Hartford, has shown many excellences in an official trial at the Washington Navy Yard.

Its chief merits consist in certainty of feed, in requiring but light power on crank, and in its ability to work up to full power from ammunition stowed in ordinary pasteboard factory packages. The fixed barrels give very good results in accurate shooting at the longer ranges. Its rapidity is about one half that of the ten-barrel Gatling for a single minute, but this difference in rapidity decreases when the fire is continued for several minutes without relieving the crankman on account of the easier working of the Improved Gardner Crank. For use aboard ship against torpedo boats' crews or the exposed personnel on an enemy's decks, where the rapidity of fire is the chief desideratum and transportation of ammunition of secondary importance, its comparative slowness of fire makes it compare unfavorably with the Gatling. For shore work and in the field generally where transportation is the main problem to solve, and where perhaps five hundred rounds per minute is sufficiently rapid firing for practice against personnel and animals, its lightness, easy working and certainty of feed make it compare very favorably with the Gatling.

NOTE.—In preparing this article the writer has consulted and freely extracted from the Ordnance Reports of the United States, Army and Navy, of England and of Sweden, from the writings of Maj. Genl. W. B. Franklin (late U. S. A.), Dr. R. J. Gatling, Lieut. Comd'r Wm. M. Folger, U. S. N., Capt. J. F. Owen, R. A., Major Fosburg, V. C., Bengal Staff Corps, Col. Fletcher, Scot's Fusilier Guards, from the Journal of the Royal United Service Institution, and from the Revue d'Artillerie. French official reports were not attainable.

In the design of the model of the arm as at present constructed, more attention seems to have been paid to the preparation for withstanding of severe tests than to the development of the particular merits of the system. This is apparent in the weight of the case, which is two-thirds that of the entire arm. The gun with twenty-six inch barrels weighs one hundred and twenty pounds; the Navy Gatling with twenty-four inch barrels weighs one hundred and eighty pounds. To the writer it would appear a simple matter to so model the piece that the weight should not exceed ninety pounds when thirty-two inch barrels were used. Such an arm provided with a light and firm mount might be convenient in tops, on poops and on forecastles, for a sort of machine gun sharpshooting; while ashore, where every pound of gun dragged takes a pound from the ammunition transporting capacity of the crew, it would be admirable.

It seems curious that the gun has never been developed in this direction, if not for naval uses, for use on pack animals with mounted shore troops, but it never has and perhaps never will be. Even in its present condition it is recommended for mountain service by Captain Jocelyn, R. A., in the R. A. Prize Essay for 1881. This arm is now named the Field Duplex Machine Gun.

When there is but one musket calibre machine gun per ship, it is evident that that gun must be efficient for all naval uses, aloft, on deck, in boats and ashore, and the short navy Gatling was designed to fulfil these various duties as nearly as may be. In order to allow the storage of ammunition in bulk when the gun was landed, the Bureau of Ordnance adopted a feeder by means of which cartridges can be fed to the piece from any pasteboard package of which the cover is removable—like those used by the Union, Winchester and United States Cartridge Companies—by entering one row at a time. This single way feeder was not entirely satisfactory at the time of its adoption in 1880; since that time a device for feeding both rows of cartridges to the gun has appeared, called the Bruce feeder. The Gatling Gun Company is now engaged in perfecting it with fair prospects of success.

If not entirely successful upon the gun ashore, this feeder will be very convenient for filling cases aboard ship, since with it two men can fill as rapidly as ten without it. Two other feeds are being experimented with, but it is very doubtful if anything better than the feed case will be developed for volley firing.

The McLean guns have had an exhibition at the Washington Navy Yard, in which they seemed to show that they were impracticable.

It is never safe to assert that any invention is entirely worthless, but it is difficult to comprehend how, with the principles embodied in it, there can be anything of value in the McLean system of machine guns.

The result of the trials of four competing musket calibre machine gun systems at Shoeburyness last winter puts the Nordenfelt and English Gardner ahead, and the Gatling and American Gardner astern, from the English standpoint.

But it should be borne in mind that in these trials some of the more important features of machine gun systems were put aside or lost sight of.

There was no question of mobility of piece or transportation of ammunition, while the penetration, velocity and range tests showed absolutely nothing as regards the comparative merits of the systems; for it is evident that these must be the same when the same barrels and ammunition are used, provided the breech mechanism furnishes a good gas check, without which it is hardly worth while to consider a system at all. In these trials the American Gardner system was heavily handicapped by being put into a four-barrelled gun instead of a two-barrelled one, for which it is designed, by having short barrels, by having no experts to serve it, and by a singular growth in the size of the chambers, which it is claimed was the cause of an otherwise unaccountable failure in extraction.

The Gatling system was unfortunate in not going to trial in a gun with a removable crank, which would have allowed the same piece to show rapidity and accuracy, and in either a mistake in chamber sizing or in singularly bad luck in the matter of strength of heads of the cartridges fed to it.

In this country but little is being done toward producing machine cannon. The single barrelled 1.45″ calibre anti-torpedo boat Gatling after a trial at Sandy Hook has received favorable mention from the Army Light Artillery Board; and the Lowell Gun Company has in wooden model an 1″ calibre gun.

In England renewed competitive trials between the Hotchkiss and Nordenfelt machine cannon are spoken of as about to take place.

France, after proving its excellences in Tunis, is largely increasing her Hotchkiss revolving cannon armament, and several other countries are following in her wake.

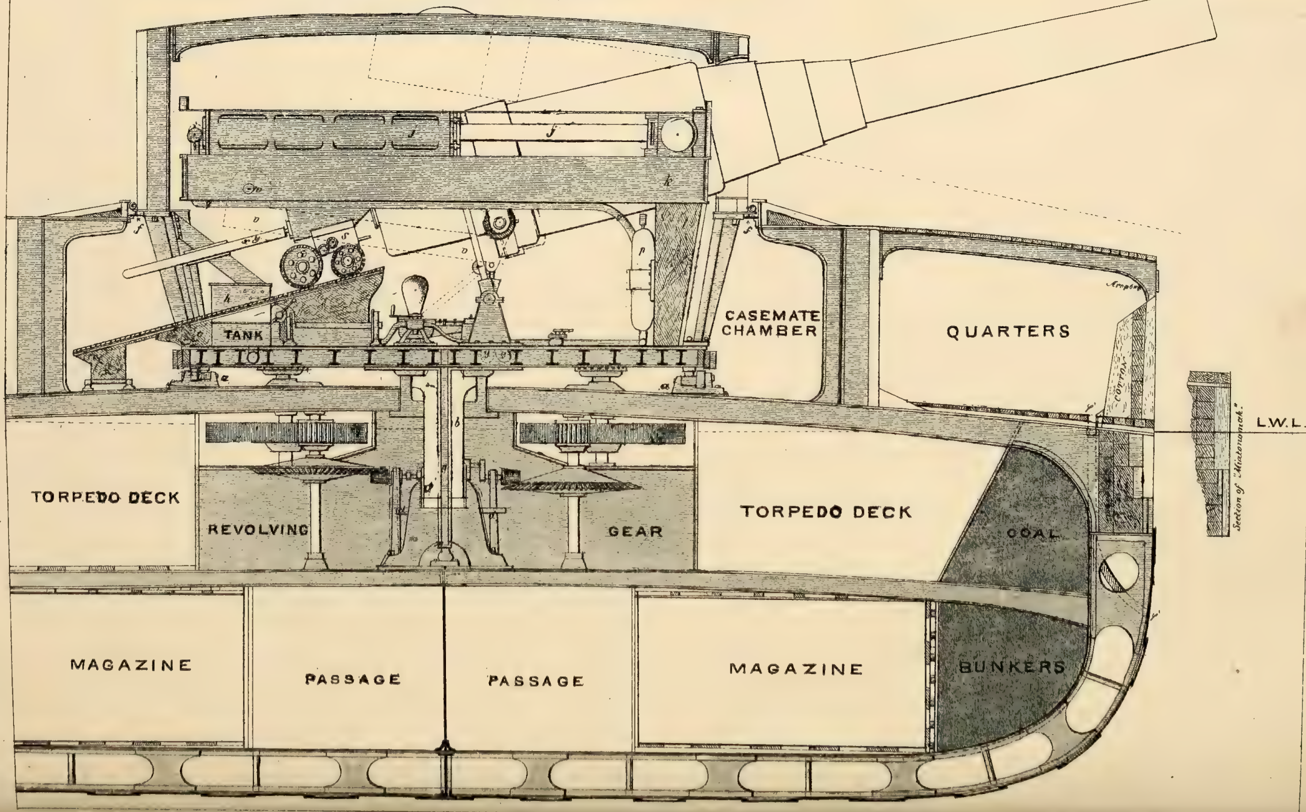
Germany has adopted the Hotchkiss for her machine cannon armament.

NOVEMBER 10, 1881.

PLATE I.

SCALE IN FEET

SECTION OF TURRET THROUGH 1.1.



I. FRIEDENWALD, LITH. BALTO.

NAVAL INSTITUTE, ANNAPOLIS, MD.

DECEMBER 8, 1881.

LIEUT.-COMMANDER C. M. THOMAS, U. S. N., in the Chair.

A MODIFIED MONITOR, WITH A NEW METHOD OF MOUNTING AND WORKING THE GUNS.

BY ENSIGN W. I. CHAMBERS, U. S. N.

The following paper contains a description of (A) a method of mounting and working heavy guns in small turrets, as invented by myself, and (B) a vessel having the same displacement and general dimensions as the U. S. S. Miantonomoh, fitted with the turret and apparatus described.

A.

The idea of a mixed battery of large and small guns and other offensive weapons for an ironclad of the monitor type, is the groundwork of my plan. Plate I represents a turret whose interior diameter is the same as that of the Miantonomoh, 21′1″, with the armor increased in thickness by 5″ of steel; mounting one 71-ton 15.6″ Krupp breech-loader and two 10″ B. L. rifles on the Krupp system, both modified as hereinafter specified. The turret (see plan) is divided into three separate compartments by four iron bulkheads *c c′*, which serve the double purpose of separating each of the guns, with its apparatus and gunners, from the others and binding the parts of the turret in a strong, compact manner. By thus mounting the heavy gun directly on a diameter of the turret, we reduce the size of the port to a minimum without the aid of muzzle pivoting, which, for so large a gun in such a small turret, would be rather a difficult and undesirable matter. The two smaller guns, however, are necessarily so fitted as to pivot in the port; all can be loaded from

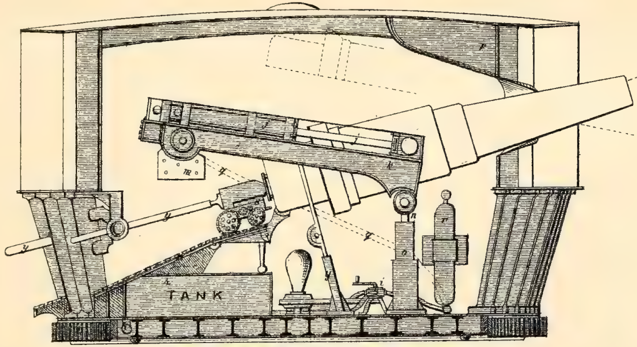
below by hydraulic machinery, with the turret *in any position*, and the two directing heads of the ship and guns are stationed in the two compartments at the sides entirely protected by the best portion of the turret armor itself, and communicating with all parts of the ship by turret indicators, or voice tubes.

The turrét is not designed to be lifted; it is supported by the rollers *a*, which have other friction rollers for their axles and frustums to revolve upon, so arranged as to be readily removed or replaced singly at any time; and by the spindle *b*, which is hollow to admit of a steam pipe and wires. This spindle rests on two long wedges *d* in the bed casting, by means of which an equal strain can always be brought upon the supports of the turret. Wobbling motion of the turret is prevented by the small steel spheres *e*, which are placed between the outer edge of the turret and the inner edge of the glacis, and water is prevented from getting below in any quantity by the rubber gasket *f*.

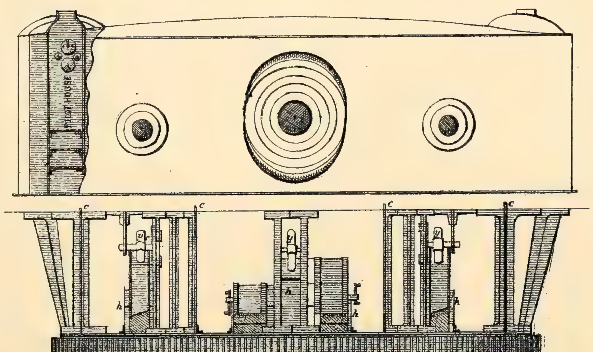
Each compartment contains a pump of the Worthington, Blake, or other suitable pattern, supplied with steam by the pipe *g*, and exhausting into the tanks *h*, if water be the fluid used; and these pumps operate by means of hydraulic rams all the functions of the gun gear. In order to allow one trustworthy man to control each function, I have placed a three-way valve *i* and four-way valve *i'* in connection with the pumps, by means of which the stream may be directed either to elevating, running out, opening the breech, or loading. The recoil-check and running out gear is for each gun a pair of cylinders and pistons *j j'*, directly in rear of the trunnions and supported by the iron or steel box girders *k k'*, which, in the case of the large gun, are riveted to the bulkhead *c*, and rest on the oak struts *l*.

For the small guns these girders or slides are supported at the rear end by cheeks *m* bolted to the bulkheads, and at the front ends by the pistons *n* of the rams *o*, through which the elevation and depression is given to the guns, which have a preponderance of 0. If it should be considered that additional apparatus would be necessary for this function, it can be fitted to act in conjunction with these rams upon the breech of the gun, but I think it would unnecessarily complicate the machinery. Having in mind the possibility of a shot knocking off the muzzles of these smaller guns, I have located the guide-beams *p*, which would probably admit of the gun being worked with its muzzle gone. Elevation or depression is given to the large gun by the side rails *v*, shown in dotted lines, pivoted to

PLATE II.

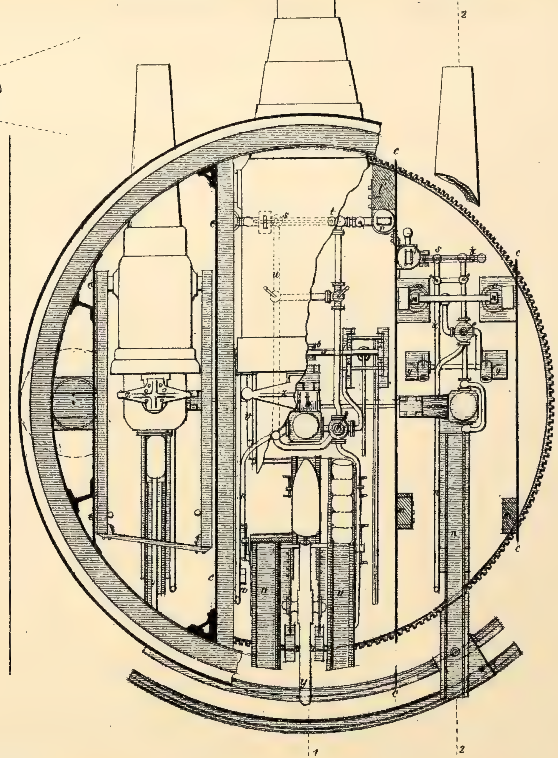


SECTION OF TURRET THROUGH 2.2.



FRONT OF TURRET AND REAR OF PLATFORM

TURRET PLAN.



INVENTED AND DRAWN BY
W. I. CHAMBERS, ENSIGN U.S.N.

I. FRIEDENWALD, LITH: BALT.O.

the slides at w, which support the breech of the gun through the two composition trucks x attached to it. The front ends of these rails are supported by the first joint of the pistons of the rams y, by which they receive their vertical movement.

When the gun is discharged, the pistons in the recoil cylinders force the water through the pipes $q\,q'$, into the air chambers $r\,r'$, which, communicating with spring valves $s\,s'$, set to the required pressure for resistance by a screw nut on the levers at $t\,t'$, lift those valves and allow the water to escape through the pipes $v\,v'$, into the tanks, the springs always offering the required amount of resistance. After recoil, the gun would be run out, if necessary, by simply turning the valve lever $i\,i'$ in the proper direction and putting on the pump. Then, if not already in the loading position, this would be quickly effected by simply allowing the fluid to run out of the rams $y\,y'$ into the tank. The pistons of the rams y and y' are jointed or in sections with a spring clutch to hold them stiff when lifted to engage the cross-heads $z\,z'$ of the breech plugs. The partly curved rod α connecting the side rails v rests on β in loading position, so that the same ram that elevates can be used in lifting the breech plug of the large gun. When the plug is lifted, a stream of water from the loading rams $\gamma\,\gamma'$, or a jet of steam is let into the gun, blowing out the smoke and washing out the bore; then a thin cylinder of steel is pushed into the breech to guide the charge home, which in the meantime has been brought up to the loading position. The projectiles and charges, after having been placed on the truck carriages $\delta\,\delta'$, are hoisted from below by hydraulic lifts, then run upon the cars Σ by which they are brought in rear of the cogged tracks $\pi\,\pi'$, and the cars are clamped to the turret so that they can revolve with it. The truck cars $\delta\,\delta'$ are then run upon the tracks, which may be either single or double for the large gun, but single for the small ones, as their charge is so light that it can be carried by hand.

With the turret mounted in the casemate as shown, the hydraulic rammer is necessarily made in two sections, as its cylinder will not admit a piston rod long enough to push the projectile completely home. When the gun is loaded, the steel cylinder can be withdrawn by the rammer, and the plug, which is slightly wedge-shaped, is settled into its seat. The elevation is then given, and an electric or a friction primer inserted into a vent hole in the centre of the bottom of the plug, which communicates at right angles with

another extending from it in line with the axis of the bore to the powder chamber. The readiness of each piece to fire is signified by the captain of the piece turning an indicator pointer, which at the same time completes the circuit, and it may then be fired by the officers in the pilot-houses, either by means of electricity or by word of command through a voice tube.

It is believed that the various parts of this turret can be easily duplicated or repaired, and that there is ample room in it to contain the few men necessary to work the guns. Although its dimensions are small, it admits of a recoil of 7′ 3″ for the large gun, or nearly twice as much as the greatest recoil of the 100-ton Italian gun mounted in a similar manner at the Spezia trials, October 20, 1876.

In order to err on the safe side, I selected the Krupp model, which is the longest for equal powers, and to exaggerate the unfavorable side of the conditions, as well as to give a breech preponderance, I moved the trunnions forward 10″, and yet have nearly twice the distance actually necessary for the recoil of the gun in this small turret. My modification of the Krupp breech-closing apparatus is probably the only style that could be used conveniently in these compartments, but it appears to me simpler and stronger than any other extant, as no screw or locking-gear is required and its own weight closes the apertures.

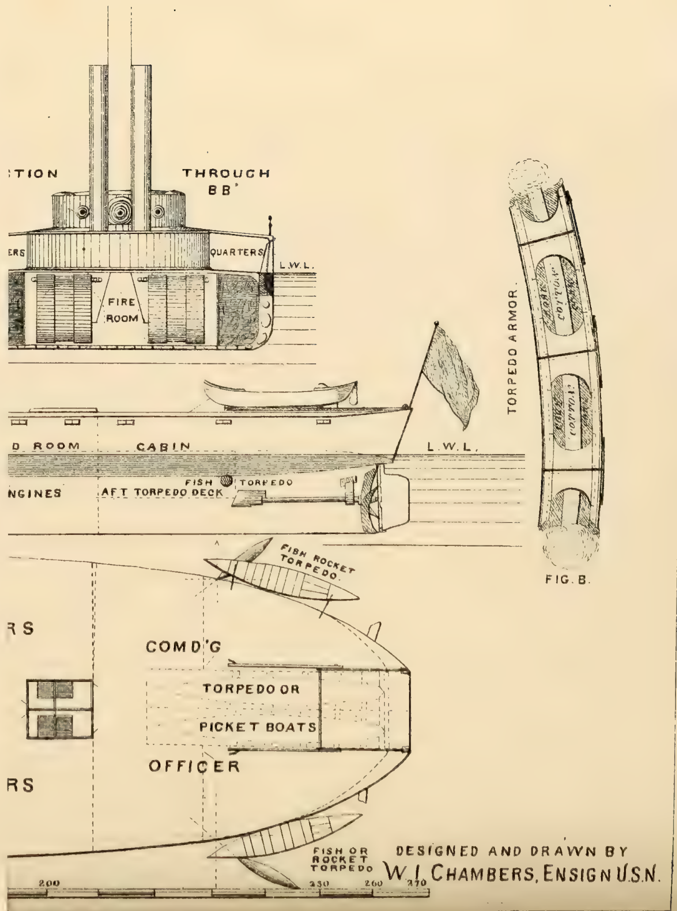
Advantages claimed for this Turret.

1. Greater weight of guns for given size of turret.
2. Separation of the guns with their attendant machinery.
3. Facility of loading heavy guns in any position of turret.
4. Non-liability to premature explosion of guns.
5. Best possible protection of pilot or directing officers with least weight of pilot-house.
6. Compactness and strength.
7. Facility of repair of working parts.
8. Smallness of gun-ports.

The question of getting this large gun in its position in the turret has not been lost sight of in designing the casemate and turret.

B.

The light draft of the U. S. S. Miantonomoh being extremely desirable for iron clads of her type and size on our coast, and



DESIGNED AND DRAWN BY
W. I. CHAMBERS, ENSIGN U.S.N.

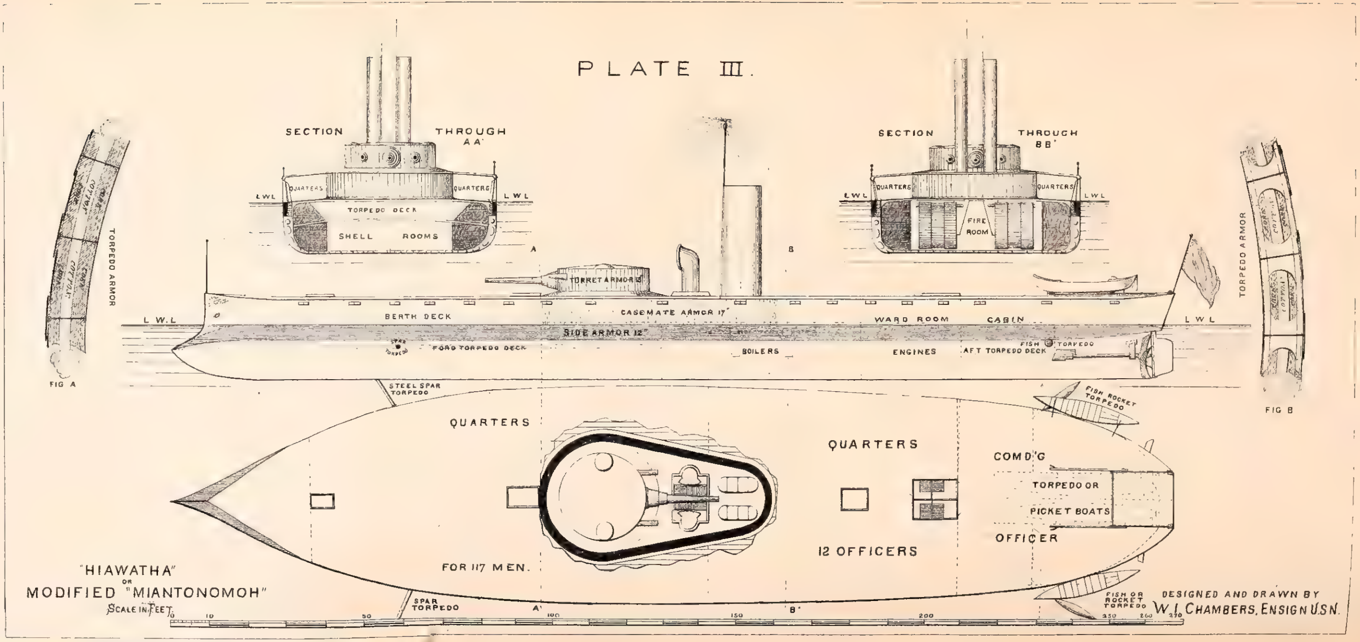
her calculated speed being very satisfactory, I have endeavored to modify the internal arrangements and armor of that vessel to suit the requirements of this turret and with apparent great advantages. For convenience in description, I will call the modified craft the *Hiawatha*, which, with the exception of a little longer ram and a corresponding decrease in the overhang of the stern, possesses the same displacement tonnage and lines below L. W. L. as the completed Miantonomoh.

The *Hiawatha* (Plate III) has but one turret, of compound armor 15″ in thickness, mounted in and above a casemate of compound armor 17″ in thickness, which encloses the working parts of the turret, the bases of the smoke-pipes, air-ducts, and the casemate hatchway. The smoke-pipes, or funnels, are two in number, elongated in section and so disposed as to allow a fire of all three guns directly astern with a complete view all around the horizon from the pilot-houses; they are also braced by three light bulkheads connecting the parallel faces of each funnel for a distance of 13′ above the casemate. The air-ducts are telescopic and lowered when the guns are trained over them. The base of the turret is protected above the casemate by a steel glacis 3″ thick (see plate I), whose section is 36″ at base and 8″ high, and the base of the casemate has a similar glacis of solid steel 18″ by 6″.

The water-line deck is covered with a 2″ steel armor bending down as shown by the dotted lines at the bow and stern, and the side armor (see plate III, where a graphic comparison is given with that of the Miantonomoh) is equivalent to adding 5″ of steel to the whole belt of the Miantonomoh's side armor from the L. W. L. down to three feet below it, making 12″ compound armor in place of 7″ iron, 10″ compound instead of 5′ iron, and 5″ compound in place of 3″ iron. The wood backing, however, has been correspondingly decreased in the *Hiawatha* to preserve the original thickness of side. Additional bulkheads and compartments have been added and stowage capacity below the L. W. L. gained by the removal of quarters from below.

A freeboard of 7′ 10″ is gained, as well as airy, comfortable quarters, by building a light superstructure of ⅜″ steel plates above the water-line deck. This is not intended to resist the flight of projectiles; and in order to temporarily stop the hole made by a projectile through both ways, a wedge-shaped strip of light pine planking is secured to the inner edges of the upright superstructure beams, and

PLATE III.



SECTION THROUGH AA'
QUARTERS
QUARTERS
L W L
TORPEDO DECK
SHELL ROOMS
SECTION THROUGH BB'
FIRE ROOM
TORPEDO ARMOR
FIG A
TORPEDO ARMOR
FIG B
TURRET ARMOR
CASEMATE ARMOR 17"
BERTH DECK
WARD ROOM
CABIN
SIDE ARMOR 12"
SPAR TORPEDO
FORD TORPEDO DECK
BOILERS
ENGINES
AFT TORPEDO DECK
FISH TORPEDO
STEEL SPAR TORPEDO
FISH ROCKET TORPEDO
QUARTERS
FOR 117 MEN.
QUARTERS
12 OFFICERS
COMD'G OFFICER
TORPEDO OR PICKET BOATS
SPAR TORPEDO
FISH OR ROCKET TORPEDO
"HIAWATHA" OR MODIFIED "MIANTONOMOH"
SCALE IN FEET
DESIGNED AND DRAWN BY W. I. CHAMBERS, ENSIGN U.S.N.
I FRIEDENWALD LITH·BALTO

her calculated speed being very satisfactory, I have endeavored to modify the internal arrangements and armor of that vessel to suit the requirements of this turret and with apparent great advantages. For convenience in description, I will call the modified craft the *Hiawatha*, which, with the exception of a little longer ram and a corresponding decrease in the overhang of the stern, possesses the same displacement tonnage and lines below L. W. L. as the completed Miantonomoh.

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A freeboard of 7′ 10″ is gained, as well as airy, comfortable quarters, by building a light superstructure of $\frac{3}{8}$″ steel plates above the water-line deck. This is not intended to resist the flight of projectiles; and in order to temporarily stop the hole made by a projectile through both ways, a wedge-shaped strip of light pine planking is secured to the inner edges of the upright superstructure beams, and

inside this another thin iron skin is built (see plate III). The spaces between the two skins and the wood strip are packed with non-inflammable cotton, compresssed to a weight of 15 pounds per cubic foot.* Automatic scuppers arranged in pipes (φ φ', plate I.) and distributed at convenient intervals along the waterways inboard of this coffer-dam, would do much toward carrying off superfluous water; and with the arrangement of the ship's bottom as hereinafter specified, no danger would accrue from the injury or leak of these pipes, provided that they could simply be plugged from the top in event of damage to the valve.

Another feature of this superstructure is that it covers two steel torpedo-boats, forty feet in length, in compartments at the stern, the bulkheads of which furnish desirable strength for that part of the vessel. These boats can be readily hauled in or out through doorways, as the water-line deck bends down 12″ at the stern. They are supposed to be fitted with machine guns for picket duty and cutting out, or spar torpedoes for detached service, as the case may be.

That part of the Miantonomoh occupied as quarters I have designated, in the *Hiawatha*, the torpedo-deck, and see no reason why arrangements for two steel torpedo-spars similar to the bow spars of the Alarm should not be made on this deck, as well as two tubes for discharging either rocket or fish torpedoes from each quarter.†

Two light, telescopic steel masts are placed next to, and connected with, the smoke-pipes along the curve of their forward sides for use in signalling and displaying the electric light. There being one light for each mast, any class of signals could be transmitted by persons stationed in the casemate under cover.

I have long thought that some arrangement of torpedo armor will eventually be found which will prove effective enough to render a vessel's destruction by torpedoes a more difficult matter than it is now-a-days; and I suggest the following device (A and B, plate III), knowing that experiment only could determine its effectiveness.

I imagine the ship to be built with as light a hull as is consistent with a requisite amount of stiffness and safety, on the bracket-plate

*I know of no experiments on anything of this sort, but it seems to me that the holes made by a projectile passing through the structure on both sides of the vessel wou'd be effectually plugged by the expansion of the cotton due to its state of compression and the effect of moisture.

†It appears to me that a fish torpedo, in event of being chased, and a spar torpedo in attempting to ram or being rammed, is about the right disposition of that arm of defense; and that fish or rocket torpedoes at the bow would be more erratic in their flight than those discharged from the quarter of a ship under way.

longitudinal frame system, the inner skin being of steel and heavier than the outer, which is of wrought iron. The skin compartments thus formed are filled in with two layers of cork, between which is packed compressed cotton as in the superstructure, the iron forming the compartment having been previously thickly coated with red lead and tallow. In conjunction with this device, I have conceived of rubber bags similar to, but lighter than, the balsas or life-rafts in common use, fitted in all compartments below the torpedo-deck not designed to contain heavy material, having permanent hose connection to the main blowing-engines, and rolled up snugly between the beams when not in use. When apprehensive of danger from torpedoes, the blowers could be turned on to these connections, thus inflating the bags and so filling such compartments with air as to admit but very little water. These simple devices, in conjunction with air-tight hatch covers, pumping engines, and torpedo-nets would probably render the torpedo, as an arm of offense, very much more uncertain in its destructive power than it is at present.

The boilers and engines of the Miantonomoh are all that could be desired for the *Hiawatha* unless they could be separated into two groups by fore and aft bulkheads; but as this would necessarily be done at an increase of weight in a ship of so light a draft, and as there is depth of hold enough left in the *Hiawatha* for the substitution, I see no reason why the two ships should not have the same boilers, engines, and speed.

The curve of the water-line deck and the volume of the casemate give the *Hiawatha* a large margin of safety, as it requires about 28 tons additional weight at the load draft to sink her one inch.

In the Miantonomoh the hull weighs .50 of the displacement tonnage, but on good authority this can safely—and advantageously to torpedo armor—be reduced to .35; but for the sake of a margin on the safe side I will suppose it reduced to .40. This will give for the *Hiawatha* an additional 328 tons to be placed below the L. W. L., and I have disposed of it as follows:

Additional coal	100	tons.
Cork, cotton and rubber for torpedo protection	82	"
Two steel 40-ft. torpedo boats	20	"
Two bow torpedo fittings and outfit	30	"
Two quarter fish torpedo fittings and outfit	60	"
Additional bulkheads below torpedo deck	36	"
Total	328	"

We will now see how the difference in the disposition of weights in the two vessels was brought about.

SUMMARY OF WEIGHTS REMOVED FROM THE MIANTONOMOH.

1.	Two turrets of 10″ iron plates with glacis	391 tons.
2.	Four XV in. S. B. guns	75 "
3.	One armored pilot-house	52 "
4.	Armor from smoke pipe and air duct	64 "
5.	Side armor (2′ vertical) removed	132 "
6.	Weight of wood backing and bolts for side armor removed	66 "
7.	150 rounds of projectiles and ammunition	100 "
8.	Four XV in. carriages of 18,000 lbs.	32 "
	Total weight removed	912 "

The two sets of hydraulic lifting gear for the Miantonomoh's two Ericsson turrets and the revolving gear for her after turret are offset in the *Hiawatha* by the rams, pumps, and pipes of the guns in the new turret. The Miantonomoh's heavy six-inch deck is divided into two light three-inch decks for the *Hiawatha*.

SUMMARY OF WEIGHTS ADDED TO THE HIAWATHA.

(*a*) Weight of proposed turret including	Armor	127.36 tons.
	Spindle	2.06 "
	Bulkheads (1 inch)	10.50 "
	Carriage slides	6.48 "
	Struts or uprights	8.44 "
	Bottom or table	6.80 "
	Roof and beams	1.08 "
	Water or liquid	.90 "
	Two pilot house roofs	165.76 or 166 tons.
(*b*) Complete belt of steel side armor 5″×3″		147 tons.
(*c*) Weight of casemate with beams and glacis for turret and casemate		262 "
(*d*) One 15.6″ B. L. rifle of 71 tons and two 10″ B. L. rifles of 18.5 tons		108 "
(*e*) 100 rounds for each of the three guns		139 "
(*f*) Superstructure of steel, cotton, and wood with beams and fastenings		83 "
Total weight added		905 "
Total weight removed		912 "
Leaving margin in our favor of		7 "

Let us see how this change of weights affects the stability of the two vessels.

MIANTONOMOH.

Weight above L. W. L		×	distance of c. of g. from L. W. L.	=	Moments.
1	391 tons	×	65″	=	25415
2	75 "	×	113″	=	8475
3	52 "	×	180″	=	9360
4	64 "	×	55″	=	3520
5	132 "	×	12″	=	1584
6	66 "	×	12″	=	792
8	32 "	×	113″	=	3616
Weight below L. W. L.		×	Distance from L. W. L.		52762
7	100 tons	×	108″	=	10800
Giving x the remaining moment				=	41962

HIAWATHA.

Weight above L. W. L.		×	distance of c. of g. from L. W. L.	=	Moments.
(*a*)	166 tons	×	132″	=	21912
(*c*)	262 "	×	64″	=	16768
(*d*)	108 "	×	136″	=	14688
(*f*)	83 "	×	39″	=	3237
Weights below L. W. L.		×	distance from L. W. L.		56605
(*b*)	147	×	19″	=	2793
(*e*)	139	×	108″	=	15012
					17805
Hiawatha's remaining moment, y				=	38800
Miantonomoh's " " x				=	41962
x—y giving excess of latter				=	3162

And as 912 tons is the total weight distributed we see $\left(\frac{3162}{912}=3.47\right)$ that, as the change in weights has been equivalent to lowering 912 tons about 3.5 inches, the stability of the *Hiawatha* is certainly not less than that of the Miantonomoh. It is also believed that the movable weights in the *Hiawatha* can be readily disposed of, and compartments so arranged as to give the most desirable rolling effect for the advantageous working of the guns.

A comparison of the prominent points of difference in the two vessels will not be out of place here.

	Miantonomoh.	Hiawatha.
Weight of broadside,	2028 pounds	2604 pounds.
Weight of fire ahead,	1014 "	2604 "
Weight of stern fire,	1014 "	2604 "
Weight of coal armor,	300 tons	400 tons.

	Miantonomoh.	Hiawatha.
Steaming power, full speed,	5.98 days	7.97 days.
Steaming power at 10 knots,	10.37 days or 2489 miles,	13.82 days or 3317 miles.
Penetration of heaviest projectile,	..	25″, 26″ and 28″ iron.
Thickness of turret armor,	10″ iron	15″ compound.
Thickness of side armor, thickest part,	7″ iron, 20. 5″wood	12″ comp., 15. 5″wood
Freeboard,	2′ 6″	7′ 10″
Height of battery above L. W. L.,	10′	11′ 06″

All of which makes a comparison very favorable to the *Hiawatha*, without mentioning the great advantages of the superstructure deck, the torpedo arrangements for offence and defence, and the increased stability.

These drawings and calculations have been hurriedly made on board ship, amid the annoyances naturally accompanying life in the steerage, and they may contain faults which more competent authority would readily detect, but I am persuaded that whether the arrangement of parts as here given be the best to gain the desired ends or not, the general plan is still a feasible and good one.

U. S. S. Marion, *Maldonado Bay, Uruguay, Sept.* 14, 1881.

NAVAL INSTITUTE, ANNAPOLIS, MD.

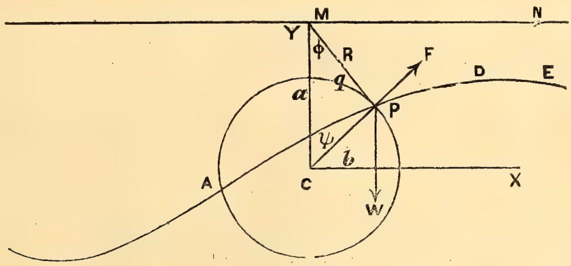
WAVE MOTION AND THE RESISTANCE OF SHIPS.

By Prof. J. M. Rice, U. S. N.

Wave Motion.

1. The trochoidal theory of wave motion, as applied to the surface of a body of water, assumes that each particle in the surface of a wave describes a vertical circle with uniform velocity.

In the accompanying diagram let ABP denote the vertical circle



described by the particle P. This particle is acted upon by three forces; W, its weight, F, the centrifugal force, and R, the resistance of the surrounding particles of water. Hence we have, ω denoting the constant angular velocity,

$$\frac{a}{b} = \frac{W}{F} = \frac{Mg}{M\omega^2 b}, \text{ whence } a = \frac{g}{\omega^2}.$$

a is therefore constant, and MP intersects the vertical line through C in the fixed horizontal line MN. It is further evident that the resistance R acting along the line q is normal to the surface.

To obtain the equation of the curve APD, we have

$$\tan \varphi = \frac{b \sin \psi}{a - b \cos \psi} = \frac{\frac{dy}{d\psi}}{\frac{dx}{d\psi}};$$

but $\quad dy = b \sin \psi d\psi, \quad$ whence $\quad y = c - b \cos \psi;$

$$\psi = 0 \quad \text{gives } y = a - b \therefore c = a.$$

Again:

$$dx = (a - b \cos \psi)\, d\psi \therefore x = a\psi - b \sin \psi + c';$$

but $\quad \psi = 0 \quad$ gives $x = 0 \therefore c' = 0;$

hence we have for the equations of the curve

$$x = a\psi - b \sin \psi \quad \text{and} \quad y = a - b \cos \psi.$$

These are the equations of a trochoid, a being the radius of the generating circle, and MN the line upon which it rolls. The curve is a prolate cycloid when $a > b$; in this case the wave presents an unbroken surface; but when $a < b$ the curve is a curtate cycloid, and the wave breaks.

2. From the values of dy and dx given in the preceding article we have

$$\frac{ds}{d\psi} = \sqrt{\left[\left(\frac{dy}{d\psi}\right)^2 + \left(\frac{dx}{d\psi}\right)^2\right]}$$

$$= \sqrt{(a^2 + b^2 - 2ab \cos \psi)} = q. \quad \text{(See diagram.)}$$

Hence $\quad ds = q d\psi.$

M is in fact the instantaneous centre of rotation of the generating circle. If α denotes the angular velocity of this circle about M, we have for the velocity with which the centre C moves

$$V = a\alpha.$$

And, denoting the length of a wave from crest to crest or from hollow to hollow by λ, we have

$$\lambda = 2\pi a.$$

Whence

$$V = \frac{\alpha\lambda}{2\pi};$$

that is, for a given value of α, the velocity of a wave is directly proportional to its length.

It has been ascertained by observation that a deep-sea wave 200 feet in length has a velocity of 19 knots per hour, and that a wave 400 feet in length has a velocity of 27 knots per hour.

The Resistance of Ships.

3. The following method of computing the resistance of ships is due to Professor W. J. M. Rankine, and although more recent investigators have advanced our knowledge of the subject, and in fact have furnished a somewhat different formula for this purpose, the method of Professor Rankine is still in use, and has been far too influential in all recent investigations to be ignored.

4. "A stream line is the line, whether straight or curved, that is traced by a particle in a current of fluid." Let us suppose a body to be constructed all of whose longitudinal sections are stream-lines, and suppose this body to be completely submerged in a frictionless fluid. It is not difficult to show that this body when once set in motion will move on indefinitely without loss of velocity. In case, however, the body is only partly submerged, its motion will tend to create waves which represent a loss of energy, and a small expenditure of force will be necessary to maintain its velocity. If we further suppose the fluid to be frictional and slightly viscous like water, an additional expenditure of force will be necessary to overcome the friction of the particles of fluid on the surface of the body, and to compensate for the loss of energy represented by the eddies caused by the adhesion of the fluid.

Of these three sources of resistance, friction is by far the most important. In fact, in certain well constructed ships, it has been ascertained that other sources of resistance may be neglected without material error. If, however, the curves forming the water-lines of a ship are not continuous and well proportioned, the loss of energy expended in making waves may be very great.

5. The first theory advanced for the construction of ship's water-lines from mechanical principles was that of Mr. J. Scott Russell. His plan was to divide the water-line into three parts, called the *entrance*, the *middle body*, and the *run*. The entrance consisted of two sinusoids; the middle body of two straight lines parallel to the keel, and the run was composed of two symmetrical prolate cycloids. The length of the run was two-thirds the entrance, and it was assumed that there must be a fixed proportion between the length of the entrance and run, and that of a wave whose velocity equaled that which the ship was expected to attain.

There is no reason to suppose that these are lines of least resistance. In fact there are many other stream-lines, differing essentially from

these, which would doubtless serve equally well. The influence of this theory has however been of considerable service to the science of naval architecture.

6. The determination of the engine-power necessary to drive a ship constructed with trochoidal lines suggested the following investigation. The preliminary statement is given in the words of Professor Rankine.

"Conceive that the trough between two consecutive crests of the trochoidal surface of a series of waves is occupied, for a breadth which may be denoted by z, by a solid body with a trochoidal surface, exactly fitting the wave-surface; that the solid body moves forward with a uniform velocity equal to that of the propagation of the waves, so as to continue always to fit the wave-surface; and that there is friction between the solid and the contiguous liquid particles, according to the law which experiment has shown to be at least approximately true, viz., varying as the surface of contact, and as the square of the velocity of sliding.

"Conceive, further, that each particle of the liquid has that pressure applied to it which is required in order to keep its motion sensibly the same as if there were no friction; the solid body must of course be urged forwards by a pressure equal and opposite to the resultant of all the before-mentioned pressures.

"The action, amongst the liquid particles, of pressures sufficient to overcome the friction will disturb to a certain extent the motions of the liquid particles, and the figures of the surfaces of uniform pressure; but it will be assumed that those disturbances are small enough to be neglected, for the purposes of the present inquiry. The smallness of the pressures producing such disturbances, and consequently the smallness of those disturbances themselves, may be inferred from the fact, that the friction of a current of water over a surface of painted iron of given area is equal to the weight of a layer of water covering the same area, and of a thickness which is only about 0.0036 of the height due to the velocity of the current."

7. That is, denoting by P the frictional resistance, by ρ the weight of a cubic foot of water, and by f the coefficient of friction, we have

$$P=\frac{\rho f}{2g}\cdot v^2=\frac{\rho f}{2g}\left(\frac{ds}{dt}\right)^2 *$$

* The explanation of the method of obtaining the formula as well as the analytical work here given differ somewhat from those given by Professor Rankine. The resulting formula is of course identical with that derived in his paper on the subject.

This resistance acts along the surface of the wave, and is therefore only a component of the force to be overcome in moving the ship. Denoting by φ the inclination of the wave-surface to the horizon, by zds an element of this surface, and by R the required resistance, we have

$$\text{Horizontal resistance} = P \sec \varphi;$$

and, since the resistance of friction is directly proportional to the area,

$$R = \frac{\rho f}{2g} \int \left(\frac{ds}{dt}\right)^2 \sec \varphi . zds,$$

in which

$$\frac{ds}{dt} = q\alpha, \quad \sec \varphi = \frac{q\alpha}{a\alpha} = \frac{q}{a}, \quad \text{and } ds = qd\psi:$$

$$\therefore R = \frac{f\rho z\alpha^2}{2ga} \int_0^{2\pi} q^4 d\psi = \frac{f\rho z\alpha^2}{2ga} \int_0^{2\pi} (a^2 + b^2 - 2ab \cos \psi)^2 d\psi .$$

And, taking out the factor a^4,

$$R = \frac{f\rho z a^3 \alpha^2}{2g} \int_0^{2\pi} \left(1 + \frac{b^2}{a^2} - 2\frac{b}{a} \cos \psi \right)^2 d\psi .$$

Expanding, we obtain the integrals

$$\int_0^{2\pi} \left(1 + \frac{b^2}{a^2}\right)^2 d\psi = \left(1 + \frac{b^2}{a^2}\right)^2 2\pi, \quad \int_0^{2\pi} \cos \psi d\psi = 0,$$

$$\text{and } 4\frac{b^2}{a^2} \int_0^{2\pi} \cos^2 \psi d\psi = 16\frac{b^2}{a^2} \int_0^{\frac{\pi}{2}} \cos^2 \psi d\psi = 4\frac{b^2}{a^2} \pi .$$

Whence
$$R = \frac{f\rho z a^3 \alpha^2}{2g} \left(1 + 4\frac{b^2}{a^2} + \frac{b^4}{a^4}\right) 2\pi,$$

or, putting $\frac{b}{a} = \sin \beta$, $2\pi a = \lambda =$ a wave length, and $V = a\alpha$,

$$R = \frac{f\rho V^2}{2g} \lambda z (1 + 4 \sin^2 \beta + \sin^4 \beta) .$$

In applying this formula λ is taken as the length of the ship on the plane of flotation and z as the mean immersed girth. To compute the value of $(1 + 4 \sin^2 \beta + \sin^4 \beta)$, the sine of greatest obliquity is determined by measurement in each water-line, and the mean of the squares of these sines is substituted for $\sin^2 \beta$ and the mean of the fourth powers for $\sin^4 \beta$.

The factor $\lambda z (1 + 4 \sin^2 \beta + \sin^4 \beta)$ is called the *augmented surface* and is denoted by S; hence

$$R = \frac{f\rho V^2}{2g} S.$$

The method of applying this formula to the determination of the probable engine-power necessary to drive a ship at a given speed is explained in Wilson's Ship-Building, pp. 125, 126 and 127.

This formula has given remarkably correct results in certain cases of ships whose lines were not trochoidal. When the lines of a ship are fine, the term $\sin^4\beta$ may be omitted in the expression for the augmented surface.

NAVAL INSTITUTE, ANNAPOLIS, MD.

December 8, 1881.

Lieut. Commander C. M. Thomas, U. S. N., in the Chair.

DISCUSSION ON THE PRIZE ESSAY OF 1881.*

THE TYPE OF (I) ARMORED VESSEL (II) CRUISER BEST SUITED TO THE PRESENT NEEDS OF THE UNITED STATES.

Commander A. P. Cooke: It would seem that our government has never had a fixed or settled policy, or any carefully devised plan, for the construction of a navy. It is a cheerful sign, therefore, and a subject of great congratulation, to have presented to us by a member of the Institute such an exceptionally able one as that embodied in the prize essay under consideration. Within the last few years nearly all the navies of Europe have been undergoing reconstruction, and nearly all States that have any pretensions to be considered of maritime importance have laid down a programme of reconstruction covering a period of years. It is only by persistently adhering to some definite plan of development, and laying down a certain amount of tonnage each year, that we can ever hope to accomplish anything. How fortunate for our country it would be if we could succeed in convincing the government of the importance of developing the plan sketched in the essay before us, and so thoroughly adapted to the needs of the United States; but if, as is said, our system of government is "deficient in the wisdom which is dependent on those expenditures that foster true economy by anticipating evils, and avoid the waste of precipitation, want of system and a want of knowledge," then we may find it difficult of accomplishment.

It would certainly be difficult to produce a more convincing proof of the real extravagance of neglecting our naval defense until after the emergency came upon us, and then constructing a fleet of cheap makeshifts, than to cite the example of our civil war, when the Navy Department spent for building and purchasing vessels upwards of $80,000,000 to bring up the navy to the strength necessary to overcome a very insignificent naval antagonist; so if ever a navy

*Owing to the lack of a reporter, only the remarks that were written are here presented.

is likely to be used in earnest, the wisdom of maintaining it continuously in an efficient state can hardly be doubted.

Since the stirring times of naval reconstruction began, the study of scientific naval architecture, greatly neglected in this country, has been prosecuted with ardor abroad, and the necessity and value of scientific procedure in designing ships has been clearly demonstrated. Change has followed change in rapid succession. Steam machinery has been wonderfully improved; large economies of fuel have been effected; the sizes and speeds of steamships have been greatly increased, and wood hulls have given place to iron, which in their turn are giving place to steel. The advances made in this period far exceed those made in hundreds of years preceding it. New elements have been introduced into ship-construction by the use of steam-power and the employment of iron. Precedent and experience have lost much of their value, and when the reconstruction of our fleet begins we shall have boldly to face the novel problems connected with the building of modern ships.

The professional education of the government constructors has been very defective. In the whole course of their training no opportunity is afforded them of acquiring even the common advantages given to men of their rank in life, and they rise to the complete direction of the construction of ships on which the safety of the nation may depend, without any care or provision being taken on the part of the public that they should have any instruction in mathematics, mechanics, or in the science and theory of marine architecture. When so much is done for the education and training of those who are to manage our ships, surely the government should, by all means, institute some system of training for those who are to build them. Can we ever hope for great progress without proper education being given to those who will have to undertake the designing and construction of our future ships?

P. A. Engineer N. B. Clark: Before answering the question, what forms of vessels are best suited to the present needs of the United States, it would perhaps be well to inquire what our possible adversaries have at the present time, and what they are likely to have in the near future, and then to build such vessels as will enable us to contend with them successfully.

With such vessels as Lieut. Very proposes shall constitute the navy, the United States could not successfully contend with even so small a power as Chili; as that country possesses several powerful armored ships, against which it would be folly to oppose unarmored vessels. The monitor type which he proposes is only suitable for coast defence and not adapted for distant service, as they would not be well suited to make so long a voyage, and would be difficult to maintain so far from a base of supplies. According to his scheme as Lieut. Very expresses it, "the unarmored fleet represents the offensive, and the armored the defensive strength of the country." In a war with Chili the armored fleet could not get to the seat of war, while the unarmored fleet could not fight with any chance of success after having done so.

That unarmored vessels cannot successfully contend with armored ones is demonstrated by the combat of the Shah and Amethyst with the Huascar. The Shah being a ship of 6040 tons displacement, and the Amethyst a corvette of

2200 tons; both vessels were armed with heavy ordnance, the Shah with 18-ton rifles, specially designed to pierce armor, and manned by thoroughly disciplined crews, while the Huascar was of only 1100 tons displacement, and was manned by "a heterogeneous crowd of insurgents." After an engagement of three hours, during which the Huascar was struck between seventy and eighty times without receiving serious injury, the combat was terminated by darkness. Owing to the wildness of the fire of the Huascar neither of the British ships were struck. Chief Engineer J. W. King is of the opinion that had the Huascar been manned by a properly disciplined crew, directed by competent officers, this combat would have resulted in the sinking of both the British ships. Besides being in possession of this same Huascar, the Chilians have two other still more powerful armored vessels, against which it would not have been wise to oppose unarmored ships.

The introduction of machine guns, firing from fifty to sixty percussion shell, or shrapnel, per minute, which will penetrate the sides of unarmored vessels at ranges much beyond those of grape and canister, making it impossible to fight guns on the open deck, will greatly curtail the usefulness of unarmored ships.

Experiments have recently been made in England on the resisting powers of light plates disposed at an acute angle, whereby it was shown that a three inch plate disposed at an angle of 15° would throw off and break up solid shot of 9 and 10-inch calibre at a distance of one hundred yards, using fifty and seventy pound charges of powder; an account of these experiments was published in *Engineering* and republished in the *Army and Navy Journal* of Oct. 29, 1881. If the system of deflecting armor is adopted it will be practicable to build vessels which will be equally serviceable for coast defence or for cruising service, and in event of war such a fleet could be sent wherever their services would be most required.

At the present time steel vessels of 4000 tons displacement are built for the merchant service, in which the weights are apportioned about as follows: hull, 1000 tons; machinery and fuel, 1000 tons; freight, 2000 tons. Such vessels attain a speed of about fifteen nautical miles per hour at sea. But modern war ships are built with a double bottom and numerous water-tight bulkheads, which augment the weight of hull from 25 to 30 or 33 per cent. of the displacement. Assuming that the hull would weigh 1300 tons, and that the weight of the motive-power and fuel would remain the same as in the merchant ship, there would still remain about 1700 tons with which, after deducting the weight of the guns, stores, masts, boats, etc., to armor the vessel. And if the armor is applied on the deflecting system, a vessel of 4000 tons displacement can be built which will have a larger measure of protection than any armored ship now afloat, combined with very high offensive powers.

As stated in a former communication,* armor protects only when struck at an acute angle; when struck at a large angle by modern ordnance, any thickness that an ordinary sized ship can carry will be penetrated. If the armor is disposed so that it cannot be struck except at an acute angle, the greatest possible measure of protection will be obtained.

* No. 1 of this volume of the Proceedings, whole No. 15.

The principal objection to the form of armored vessel which Lieut. Very proposes is that when the ship rolls the side armor is exposed, and should it be penetrated by being struck at near right angles to its surface, the shot would be deflected downward through the bottom of the vessel by impinging against the under surface of the armored deck, passing through the magazine or boilers as it went. The interior shield which was explained in a previous communication,* presents a practically constant angle to shot as the vessel rolls, and therefore would not be penetrated.

At the present time it is within the ability of either England, France or Germany to concentrate a fleet of ten or twelve first-class armored vessels at any point on our coast in three weeks after a declaration of war; these ships carry guns by which the principal navy-yards, located amidst our most populous cities, could be reached by shell fired by vessels upon the open sea.

It would be the duty of the admiral commanding such a fleet to attempt to destroy the navy-yards, but he could not do so without doing equal damage to the cities contiguous to them.

The Chief Engineer of the army in his report for 1880 stated that in order to provide an adequate defence, in addition to land batteries and stationary torpedoes, a fleet equal to that which might be brought against us would be needed. The armored vessels which Lieut. Very proposes would also be very deficient in speed when compared to the armored ships of European powers; and what an advantage is obtained by superiority in speed is shown in the combat between the Huascar and the Chilian armor-clads, where a half knot more additional speed would have enabled her to escape from her adversaries when overpowered.

In conclusion, the writer would say that he believes it to be the true policy of the government to expend whatever money may be appropriated, in building cruising vessels armored on the deflecting system, in which the armor is so disposed that it cannot be struck except at a very acute angle, and having an excess of speed over existing armor-clads so as to choose the position for combat.

It is asserted that it is not expedient for the United States to undertake the construction of heavily armored vessels at the present time, owing to the transition state of the art and the excessive cost, a first-class armor-clad costing from \$3,500,000 to \$4,000,000. It may here be stated that a responsible firm of American shipbuilders has made full plans and specifications as to cost for an armored cruiser for a foreign government, the vessel to be armored with steel on the deflecting system, and of the following main dimensions: length, 300 feet; beam, 50 feet; draught, 18 feet; displacement, 4800 tons; horse power, 6000; guaranteed speed, 16 knots per hour; area of canvas, 36,000 feet; cost, \$1,600,000.

It would certainly be better to build vessels of this class than ships like the Shah, which experience has shown are unable to contend with even the smallest armored vessels.

Lieut. J.W. Miller: The very able manner in which Lieut. Very shows the reasons why an increase and a thorough reorganization of our navy is necessary leaves little or no room for criticism. The arguments presented and the prob-

* No. 2 of this volume of the Proceedings, whole No. 16.

lematical circumstances which may lead to sudden war are concisely and aptly discussed. Notable among the strong points of his essay is the original method in which he deals with the geographical divisions of our coast. It must moreover be a source of just pride to the essayist that so many of his minor details as were applicable to cruisers appear in the report of the distinguished Advisory Board of which he was a member.

Before proceeding to offer a few criticisms on Mr. Very's proposed monitor, it is well to state that, although some have thought that the construction of cruisers should be deferred until a means of coast defence be created, *all* have agreed that a fleet of cruisers is absolutely necessary. On the question as to which should have the precedence of construction opinions differ. Let it never be forgotten that an ideal navy should be a fighting machine, and that the best of unarmored cruisers will be of little use to the defence of our home ports. The tendency to devote all our energy towards the establishment of the navy on a semi-peace basis may, if carried too far, lead to disastrous results. That the Advisory Board fully appreciated this fact is shown by the following words:

"By not recommending the immediate construction of ironclads, the Board by no means pronounces against their necessity in the future. *Such vessels are absolutely needed for the defence of the country in time of war;* and if Congress be willing to at once appropriate the large sum necessary for their construction, thoroughly efficient vessels can be designed and built in this country.

"The Board is of the opinion that in any case this subject should receive the careful attention of naval officers."

It therefore becomes our duty to give the most earnest consideration to the future type of ironclad; and it is to be hoped that the intelligence of the Institute and the service at large, shall be enlisted to supplement the views of the eminent gentlemen who have decided upon our cruisers, by plans of the future fighting vessel.

To return to the essay, Mr. Very takes the monitor system as his basis for a coast defence vessel, and suggests the following alterations:

I. He ends his side armor at the water-line flush with the crown of the deck; at that point he proposes to build up an *iron* unarmored free-board fore and aft to the height of six feet, crowned by a *wooden* flush deck.

II. He raises the turret six feet to fire over this deck.

III. He substitutes the French for the Ericsson system of revolving the turret.

IV. He carries the lower edge of his turret one foot further than at present, thus covering and protecting the turn-table, the latter of course being armored.

V. He uses *compound* armor.

As regards his first alteration, I should substitute steel for iron sides, as being lighter and better able to resist Hotchkiss projectiles; for a similar reason the upper deck should be of steel instead of wood. I agree with Mr. Very entirely in the uselessness of carrying the side armor higher than the water line; and while advocating with him the use of compound armor, I would dispose it in a very different manner.

The most vulnerable portion of the monitor system is its unprotected deck at close quarters. It must be armored to protect it from a plunging fire. I

should therefore make a turtle back armor shield running fore and aft, and sloping from the foot of the turret to the water line where it joins the side armor; round the turret it should turn upwards and outwards to deflect projectiles striking at this most vulnerable point. It will thus be noticed that the armored turn table is unnecessary. The turret also, instead of being cylindrical, should be dome-shaped. The wheel indicators, etc., should be supported on a light platform over the guns, and a small opening be left at the top of the dome for coursing the ship and facilitating the escape of smoke. The future monitor will thus present deflecting surfaces and the shot will be deflected away from the vital parts of the ship. As we cannot keep the tons of metal now thrown by the largest ordnance from penetrating by the direct building up of thick plates, we must present inclined armor and deflecting surfaces from which missiles will glance. The English hold that the advantage claimed for inclined surfaces is greatly overestimated; but an inspection of the turrets of our monitors, and of the diagrams of the Huascar after her late engagement with the Chilian vessels, shows that projectiles are deflected at quite large angles. Scientific experiment has given us another means of placing our armor, and developed the extraordinary advantage of separating the plates by an intervening air space. Instead therefore of placing my armor in a single layer, I should make it consist of two compound armor layers, separated at the water line by an interval of six feet, the air space gradually diminishing towards the base of the turret, where the combined thickness of the two layers would form the heavy breastwork reaching nearly to the lower extremity of the gun-ports.

It will be argued that so much additional armor will be too heavy for the ship to carry, but it must be remembered that the sum of two thicknesses of armor separated by an air space affords much more protection than the same amount on the ship's side, and that consequently we can use thinner plates; moreover, the weight will be distributed where it will give less motion to the ship. Mr. Very's lower turret armor is also thus eliminated.

P. A. Engineer J. C. Kafer: The writer of the essay proposes to make use of the present monitors of the Lehigh class in forming his coast defence vessel, which shall not exceed 2000 tons displacement, by increasing their sea going qualities and offensive and defensive power. In doing this he adds to the weight of the armor and machinery, builds a new superstructure and a turret support; the weight of these additions he proposes to take out of the weight of the hull and the eighteen inches of armor and backing that is now above the water line, curving the armored deck to the water line, which is to be the upper edge of side armor.

The weight saved in the eighteen inches of side armor and backing is about seventy-five tons; the remainder he proposes to take from the hull, which he says is of *wood*, and absorbs as near as can be estimated 62 per cent. of the total displacement, by making these hulls of iron with 40 per cent of displacement, thus saving 22 per cent. on a displacement of two thousand tons, or four hundred and forty tons. This with the seventy-five taken from the side armor would give him enough reserve to allow for all the changes with the exception of increasing the engine power to drive the vessel at a speeed of 11½ knots, and if it

were not for the fact that these vessels are now built of iron with very thin plating for the hulls, he might do this, but here his whole argument in favor of the change of these vessels fails, as they are not built of wood, but iron. I cannot see where he will be able to save anything on the present hulls, and surely they have little enough of reserve of buoyancy. I would like to know what increase in speed the writer of the essay expects from these vessels by the addition of thirty tons of engines and boilers and five tons coal supply, assuming that he could save five hundred tons in all.

The only way I see out of the difficulty is to build a new vessel of 2000 tons displacement, that would practically be of the same dimensions as the monitors of the Lehigh or Nantucket class, which are not far from the dimensions of the Guinea class of the Dutch navy—except that the Guinea has about 350 tons more displacement and greater draught, and for such a vessel the following is an estimate:—

Estimate of Weights for a Monitor with Light Superstructure as proposed by Lieutenant Very.

	TONS.
Weight of 35 per cent. of displacement, to armored deck,	700
Weight of deck armor, 2″ thick,	250
Weight of side armor, 4′ deep by 5″ thick,	143
Weight of side armor, bolts and fastenings,	14
Weight of 12″ backing, 4′ deep (1600 cub. ft. at 55 lbs. per cub. ft.)	40
Side plating for superstructure,	20
Deck beams and stanchions,	23
Angle iron for sides 3½ × 3½ for upper deck,	10
One turret, 10″ thick,	130
Turret support below armored deck,	20
Turret support above armored deck 10″ thick,	65
Pilot house,	30
Armored smoke pipe,	20
Cement for bottom to cover rivet heads and plates only,	18
Boats and davits, deck fittings, joiner work, plumbing, etc.,	100
Armament, ammunition and ordnance stores,	100
Anchors, chains, galley and outfit,	40
Provisions, clothing, and water,	25
Navigator, construction, engineering, and mess stores, crew and effects,	45
6″ wood lining to superstructure,	32
4″ wood upper deck,	50
Weight without engines, boilers, or coal,	1875

The weight of turret and supports as given in the essay is 278 tons against my estimate of 215 tons.

This leaves about 125 tons for machinery and coal. To drive this vessel at a continuous speed of 10 knots will require about 1200 indicated horse power, and with boilers such as are now used about 240 square feet of grate surface;

the weight of this machinery with water in the boilers will be about 336 tons, add to this the coal supply for 10 days about 240 tons, we have 576 tons; add to this the weights already estimated, 1875 tons, we have 2450 tons for about the minimum weight for such a vessel.

The Guinea is put down as having a displacement of 2340 tons, but her draught being two feet more than the Miantonomoh (16′ 4″ mean), the weight of her machinery and coal supply and the detail parts of her hull may be lighter than the weights I have estimated; her guns are 9″ 12-ton Armstrongs, but this would detract from her efficiency as a fighting machine as compared with the vessel under discussion.

The weight of armament, ammunition and ordnance stores I have taken from the weights submitted by the late Chief of Bureau of Ordnance, Commo. Jeffers, to R. Adm. Preble, in 1880; the essayist calculates the weight to be 76½ tons, but he allows for only fifty projectiles for each gun, while the Bureau estimates on one hundred for each gun; one hundred more at 400 or 470 pounds each will make a difference of twenty tons.

I would like to know Lieut. Very's reason for advocating a large number of small guns for unarmored vessels; it is generally understood that war vessels are built for the purpose of fighting, but the small guns will only be useful against unarmored vessels, and if the unarmored vessel should meet an armored ship of an enemy in time of war there would be one of two things to do, to run away if she could, or to surrender if she must; but if she had with a number of light guns to use against unarmored ships, two large guns, one forward and one aft, that would pierce the eight or nine inches of armor, she would stand a fair chance with the armored ship—if she was lucky and had good marksmen.

I know that armored ships of the English navy have been armed with a great number of small guns, but that is no reason why we should follow in their footsteps. A free expression of opinion on this subject by members of the Institute would prove very interesting.

FIG. II.

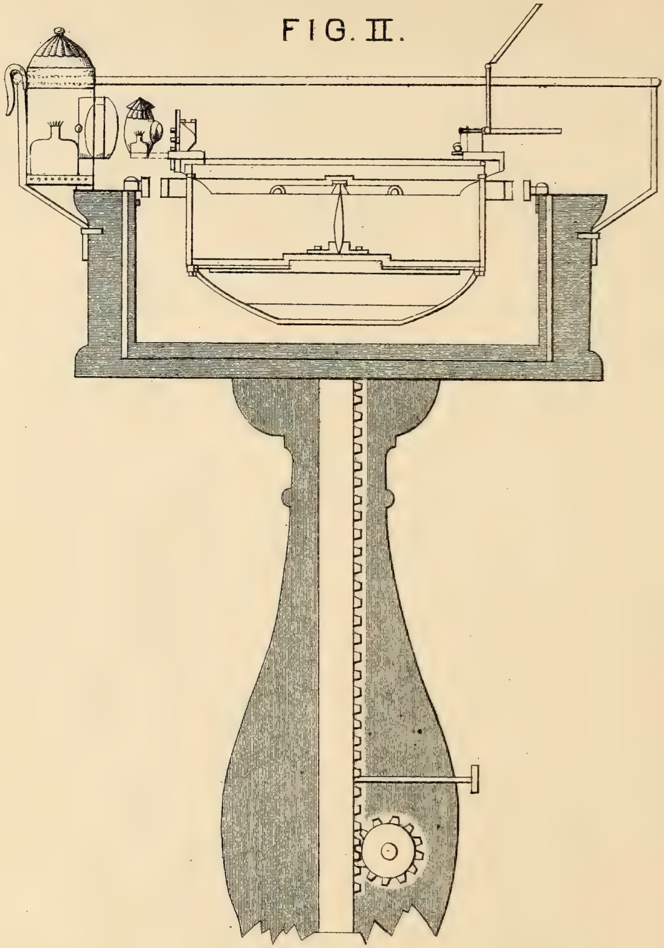
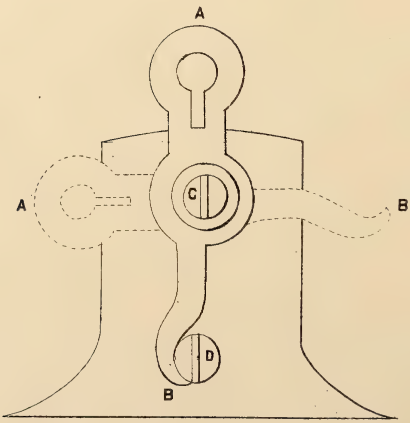


FIG. I



I. FRIEDENWALD, LITH. BALTO.

NAVAL INSTITUTE, ANNAPOLIS, MD.

AIDS IN THE PRACTICAL WORK OF NAVIGATION.

By Lieut. Albert Ross, U. S. N.

In the last number of the Proceedings of the Naval Institute, a valuable article, entitled *Aids to Navigation*, attracted my attention, and I would like to add a few aids of minor importance in the practical work of navigation, and to call attention to one of the greatest importance—the rating of chronometers by telegraph.

During the past three years I have used, with great satisfaction, several aids, which I offer for the approval of officers of the navy: A mechanical device to assist in taking bearings when compelled to use the azimuth circle on the standard compass; a method used for illuminating the standard compass, and a proposed improvement to the same; a chronometer chest, and a deck chart board.

When an alidade is not furnished and bearings are to be taken by the use of the azimuth circle, difficulty is experienced from there being no notch, or sight, on the prism to take the place of a rear sight. In fair weather the mirrors work very well, but when covered by moisture they are useless. In order to overcome this difficulty, I had fitted an eye-plate, with a sight-hole and slot. This plate is made to turn around the upper screw on the prism; the lower end, as fitted in Fig. 1, is made in that way that an observer can place it at night against the screw D, and know that when so placed, that the slot, centre of the compass and spider line are in the same plane, and that the circle is ready to be used for the purpose intended. The eye-plate A-B is made to revolve on the screw C, that the prism may be used in taking azimuths, and was made in this shape to adapt it to the azimuth circle now issued, is readily adjusted, and was found to be of very great assistance in coast work. At all times the circl with this fitting is preferable to an alidade, for bearings can be more

accurately taken than by any other method. At night, with the method of illumination used, no difficulty is experienced in finding a light in the round hole, dropping it into the slot, and reading its bearing to nearest degree, if so desired.

To illuminate the standard compass that bearings may be accurately determined at night, and relieve the navigator of many of the troubles now experienced, a movable ring is fitted, with its supports arranged, as shown in Fig. 2, that they will not interfere with the moving on it of the navigator's night-lamp—the brass bull's-eye lamp now issued. The loop on the back of the lamp fits over the ring, and the bottom of the lamp rests on the frame of the standard compass. The height of the ring is so placed that the lamp will be tilted enough to throw the light on the opposite side of the compass. The ring is made of brass wire, one-quarter of an inch in diameter; the supports are soldered in holes that were drilled to receive them, and the brass eye-bolts in the pedestal for the lower ends of the supports complete the ring and fittings. The fixture is not an expensive one, and it can be made and fitted by mechanics on board ship. Placing the lamp to the right or left of the prism, depending on the eye used by the observer, the eye-plate, spider line and compass are so fully illuminated that the object is readily found and its bearing accurately determined.

Although the work was satisfactorily performed by using the ring fitted in this way, it is open to objections on account of having to move the lamp in taking each bearing. A much better plan is to fit in the azimuth circle a socket on each side of the prism, in which a small bull's-eye lamp, made for this purpose, could be shipped. A movable counterpoise would have to be fitted, to retain the compass in a horizontal position. With the circle thus fitted, the lamp becomes a fixture of the circle, and all that is required is to move the spider line to the different objects. Fig. 2 shows the manner of fitting the ring to use the night-lamp with the old-fashioned pedestal and cover. The small lamp, fitted to the circle, is the proposed change to do away with the ring and adapt it for use with the new pedestal, the hood or cover of which will require several changes, viz.: Fit the brass hood, or cover, so that it can be turned to all points of the horizon; the glass plate, in the opening for observing the compass, should be framed and fitted with hinges; directly opposite cut a similar opening, but glass will not be needed in this. The openings for the lamps should be without glass, the glass being fitted

to the lamps instead. All of the openings should have covers, with hinges so placed that the covers can be turned *down*, but not to interfere with the turning of the hood. At sea the regular lamps can be used; but on approaching the coast, ship the bull's-eye lamp and counterpoise in the sockets in the azimuth circle, use the large openings in the cover for hand-holes to bring the spider-line on the object, the lamp openings for sight-holes, and no difficulty will be experienced in taking or reading bearings to an eighth of a point, which is as close as it is found practicable to plot them.

The Chronometer Chest.

The chronometer chest is fitted on the top of an ordinary stateroom bureau. Two blocks of wood, three inches square and the width of the bureau long, are first securely fastened to the deck. To these the bureau is fastened by long wood screws. Care is taken that it is at least one-half of an inch away from all bulkheads or stateroom fixtures. The top section is divided into three compartments, each of sufficient size to take a large chronometer with the usual padded fittings. The tops are taken from the chronometers, which reduces the height of the section four inches; but height enough must be given that there will be no danger from the most violent motions of the ship of the chronometers touching the lids, I allowed more than one-half the diameter of the largest face. The top is divided into three lids, each one covering a compartment. In the construction of the chest care should be taken that tight joints are made. Small catches are fitted near the edge of the central lid, so that two lids can be joined and raised while comparing, and that the beats of the third chronometer may not be heard. When through winding and comparing, the catches are pushed back, and the standard is available without interfering with the others. A woolen cover is spread over the top, and the chest is complete.

The hack chronometer was kept in its transporting case on a shelf near the others, and its face on the same level. The same care was taken of it as of the others, and I found this method of great benefit when using it in getting telegraphic rates.

During three years, with target practice and the usual rolling and pitching experienced by a vessel in the varied weather at sea, nothing affected the chronometers but temperature, which has more to do with the changes in rates than anything else.

The great advantages in the use of this chest, are the ease with which chronometers are handled, winding and comparing, and, from their position, being entirely out of the way. The lower drawers are used for navigation stores, and such articles as are rarely used. They are kept locked, so that no one opens them but the navigator, and he is interested enough to see that they are opened and closed with such care that no injuries from jars occur. If the bureau were built with the view of fitting the top section in this way, the frame made heavier, and the desk of the secretary drawer made to draw out, instead of the drawer, the possibility of such jars would be greatly removed. No difficulty was experienced in the use of the light-framed bureau for this purpose during the last cruise of the Portsmouth.

The Deck Chart Board.

The chart board to which attention is called is now before the Chief of Bureau of Navigation for such action as he may deem proper. Although intended for a deck board, it can be used on the cabin table, and a great saving of charts result. The board is composed of frame of ash or walnut sufficiently strong to protect the glass; a bottom board, to which the frame is hinged, to force the chart against the glass and to receive such fittings as will be found necessary to secure it in a convenient place on deck; and a plate of glass thirty-two inches square, embedded in the frame in cement to exclude moisture. The glass is tracing glass, cut just enough in the sand blast to take the mark of a pencil in plotting bearings, etc. Space is allowed on the end of the bottom board to allow charts longer than thirty-two inches to be used. By doing this, with a glass of the dimensions given, all coast and harbor charts can be used. The surface of the glass being flush with the top of the frame, the parallel rulers can be used without difficulty.

In the sample board furnished the Bureau of Navigation, ordinary vestibule glass was used. As this is cut to exclude the light, the soundings on the chart used were not as distinct as desired, but on wetting it every part of the chart was shown. With tracing-glass similar to that used in transparent slates, the board will be found useful at all times.

The great advantages of this board will be appreciated by any one who, on approaching the coast, has had to hurriedly consult the chart on the cabin table, but before approaching the chart having

to remove rain clothing, or in windy weather on deck when all the spare leads were called into action to prevent the chart from being blown away.

The expense attending this board will be for the glass. The frame and fittings can be made by any good carpenter on board ship. When we get the new ships, with the pilot-house and chart-room on the forward bridge, this board will not be needed.

Telegraphic Rates.

The greatest aid offered is the rating of the chronometer by telegraph. The great need and advantage of using the telegraph for this purpose was brought to notice while on duty at the Naval Observatory in 1872 and '73. It was proposed then to establish rating stations in each navy-yard by connecting the observatory clock and each navigation office, but from lack of funds and the newness of the idea, nothing was done. Time was then sent, as it is now, over the wires of the Western Union Telegraph Company, and you can rely upon getting accurate time wherever there is a Western Union office.

In an article of this kind, the details of receiving, and localities, time may be obtained, will not be out of place. The hack chronometer was used in the comparisons, comparing it with the standard, before and after getting the time signal, to obtain the error of the hack due to transportation.

North of New York, rates were obtained at Portland, Maine, where comparisons may be made with the clock of Cambridge Observatory, Massachusetts, at 9 A. M. and P. M., at the railroad depot; or it can be obtained, at any time during the day, at Merrill's, a jeweller who has telegraphic connection with the Cambridge clock. There is objection to getting the error in this way, as time is required to write to the observatory to get the error of the clock. The Cambridge authorities endeavor to send the 9 A. M. and P. M. instants free from error, so that it is readily seen that errors obtained by comparisons with these instants will be more reliable than comparisons with the beats of the Cambridge clock where its error is not given. At Boston, at the main office of the Western Union, comparison may be made with the beats of the Cambridge clock, and the error will also be given. At Newport, Rhode Island, at the railroad depot; at Portsmouth, New Hampshire, at the railroad depot.

Time could also have been obtained at Salem and Gloucester, Massachusetts. The time sent over the wires of the Western Union north of New York is 9 A. M. or 9 P. M. of the Cambridge clock, and is a time signal giving those instants. The beats of the clock, every two seconds, are heard for one minute before, the 58th second is omitted, and the single beat following denotes 9 A. M. or 9 P. M. Boston State House time, and this is the time sent over all of the New England States. As the Cambridge clock keeps the time of the meridian of Boston State House, the longitude to be used is 4^h 44^m $15^s.46$ W. In Boston and wherever direct connection is made with this clock, beats every two seconds will be heard, except the 58th second, which is omitted to denote the minute, and twenty seconds, which are omitted to denote each five minutes. The office clock having been set by the 9 o'clock signal, the time is thus always accurately known.

Time-balls are offered in Boston, New York, and Philadelphia. In New York, at 11^h 55^m A. M. the ball is hoisted half way up the iron flag-staff on the tower of the Western Union office. It can be seen by all shipping at the New York and Brooklyn docks and by vessels in the bay below Quarantine. The ball remains at half mast from 11^h 55^m to 11^h 58^m, when it is hoisted to the top of the staff. At 12^h 00^m 00^s the ball is dropped by an automatic clock in the observatory at Washington, and the instant the ball starts is New York noon, longitude 4^h 56^m $01^s.65$ W. If, on account of high winds, the ball fails to fall at 12^h 00^m 00^s New York time, it will remain mastheaded until 11^h 05^m and dropped at that time. In such cases a small red flag will be hoisted at 12^h 01^m and kept flying until 12^h 10^m. The time of falling is registered automatically in the Western Union office, and the error is published in the New York morning and evening papers. By means of the chronograph in this office the error can be read to hundredths of a second. Time is also received from the observatories at Cambridge, Massachusetts, and Allegheny, Pennsylvania.

Time-balls do not give as satisfactory results as the comparison with the beats of the clock as shown by the telegraphic sounder. By taking the hack chronometer to the Western Union office, through the courtesy of Mr. Hamblett, who has charge of the time service, every facility will be offered to compare it with the beats of the Washington observatory clock, and the instant of New York noon noted free from error, except that due to the hearing of the person

making the comparison. A check on this work may be made by waiting $11^m\ 10^s.34$, when Washington noon will be received. At $11^h\ 56^m\ 45^s$ Washington time, the beats of the Naval Observatory clock commence. The 29th, 55th, 56th, 57th, 58th, and 59th seconds of each minute are omitted, and a single beat denotes Washington noon, longitude $5^h\ 08^m\ 12^s.09$ W. The single beats of the clock with the omissions as stated, followed by a single beat, completes the time signal as used for Washington and New York noon. North of New York the Naval Observatory time-signal cannot be obtained. South of New York the time-signal denoting Washington noon is received, and can be obtained by applying to the operators of the Western Union. No charge is made, and every facility offered for direct comparison, by sound, of the time-signal and the chronometer in question.

The great advantage of rating in this way is the fact that the hearer is never in doubt as to the result obtained, its entire reliability, and the certainty of getting satisfactory rates at times desired. Thus sea rates can be ascertained which you cannot rely upon getting by any other method. It is always practicable to get from the telegraph office, errors before going to sea; on returning, the Western Union again offers another error, by which the sea rate is accurately determined. By sights you never could rely upon getting *true* sea rates, the weather seldom permitting satisfactory sights before going to sea or on the immediate return. In the establishment of rates by equal altitudes, etc., so many errors creep in that are not under the control of the navigator; instrumental errors, those of the person marking time, errors of longitude, personal errors, and others that will come to the mind of any one who has acted as a navigator. By telegraphic rates only *one* error can come in that is not under the control of the person making the comparison, and that is of the ear. The signal is never in doubt; if received at all, you know the exact instant of time denoted by the signal. It is the only method by which the navigator can have everything in his own hands, and feel that entire confidence in the result that it is absolutely necessary to feel in order to make a reliable and successful navigator.

When chronometers have been received on board from the navigation office, and been allowed several days in the place assigned them for the cruise, the observatory rate should be checked, and if necesary a new one established. No difficulty will be experienced in doing this, as I have shown, on our own coast; and I have been informed

that our ships have received time from Greenwich, at St. Johns, Newfoundland. In Europe, time balls are very much in use, and propositions have been made to the Bureau of Navigation to establish them in the principal maritime cities of this country.

It is not intended that this proposition will entirely take the place of rating by sights, even on our coast, where telegraphic rates can always be obtained. That question is of as much importance as it has ever been, and cannot be thrown aside as long as there are coasts without observatories and telegraphs. Rates by sights should be ascertained, and the telegraph office offers the opportunity to check the work, and a valuable means of establishing the personal error of the observer. The satisfaction gained from doing so would be amply repaid by the confidence in his work thereby established. Thus the telegraph will prove a great aid in this respect. When so much depends on the accuracy of the chronometer, every method that will aid in arriving at greater accuracy, or increasing the confidence of those who make use of it, should be developed to its fullest extent, that the greatest good may result from its employment. Of the great number of wrecks reported each year, the number wrecked from the lack of knowledge of the performance of the chronometer would certainly astonish the shipping interests of the world. Investigate the causes of wrecks and more than one-half can be traced to this cause. The preventable causes should be taken for any wreck caused by ignorance of the performance of the chronometer, should be placed under that head. How can any navigator or merchant captain have confidence in a chronometer if he does not rate it frequently, paying attention to the temperature between ratings, that its performance under similar circumstances may be expected. To a person that does not do so, temperature does not enter into the subject of the management and study of his chronometer; and changes of temperature, sudden though they may be, will not bring changes of rate to him, nor make any difference in his approach to the coast. Overrunning the reckoning is a too frequent report as the cause for the loss of so many lives. When it is possible for every merchant captain to rate his own chronometer by time ball or telegraphic sounder, errors will be more frequently ascertained and rates established. And here come in the benefits of this method if adopted; for *then* it will be possible for him to perform the work. The more he handles this subject the better he will become *acquainted* with the movements of his chronometer under all circumstances, and good results must

surely follow that better knowledge. The captain that can rate his own chronometer, and have the confidence in it that is gained by this method, will not be the one to overrun his reckoning, or run any unnecessary risks in the navigation of his ship.

The confidence resulting in a continuance of this system of management would be so great that captains would not attempt sighting different points to test chronometers, and thereby unnecessarily jeopardizing their ships and the lives of their crews. A case in point was shown while the Portsmouth was at Fayal, in 1880, by a merchant ship bound from Rangoon to Liverpool. The captain said he was not satisfied with his chronometers, and wished to sight Pico to test them. At 4 A. M. he found himself on the beach, the ship a total wreck and eight lives lost. Had this captain rated his own chronometers, an error of this magnitude could not have happened, and the course would have been laid for Liverpool, where he would have had a lighted coast on which to run his ship, without losing so many lives.

As this subject is of vital importance it certainly deserves full investigation, and, if found as valuable and reliable as the writer deems it, should be given, in all of its details, to the navy, and particularly to the merchant marine.

The proposition to establish rating stations in each navy-yard, at Hampton Roads, Port Royal and Key West, for the navy, has been before the Chief of Bureau of Navigation for some time, and last year I was informed that all that was now needed was an appropriation to put them in force. As all of the yards have telegraphic connection, this can be accomplished at small expense. But this proposition refers only to the navy. Why should it not be carried far enough to tender its benefits to the merchant service? Would not the number of wrecks be decreased thereby, and thus prove a boon to that branch of the service by keeping afloat a few years longer the few ships we have now the name of protecting? If we cannot protect them in any other way, let us at least attempt protection in this. The practical working of this system would put in the hands of those most interested the means of checking chronometers whenever in port, checking the rates given them when they are put on board, and testing each chronometer as to its reliability before going to sea. This last feature does not apply to instruments furnished the navy; but in the merchant service, where so many hired instruments are sent to sea, it becomes one of the

greatest importance. Evidence given in this way of the unreliability of a chronometer would send it ashore before any harm is done, and would throw on the hands of instrument-makers many chronometers that are now at sea. It would compel those who furnish instruments to furnish only reliable ones—and can any one doubt that such a course would be of great benefit to all concerned in the safe navigation of the sea?

In order to use this proposition to the best advantage, it is proposed to establish in each maritime city of importance, in the Custom House, an office, in charge of an officer of the Navy, with the number of assistants deemed necessary for the duty shown hereafter, for the purpose of giving accurate time to the place and shipping, reliable rates for chronometers to all applicants; to distribute or sell, as the case may be, the charts, sailing directions, light lists, notices to mariners, and other information that is now prepared at great expense by the naval authorities; and thus, the information put in shape by naval officers will be put in the hands of those desiring it by the same authorities. The Navy is now furnishing a portion of this information, but it is not furnished through naval channels, instead of which, it is found in all sorts of establishments. In many cases the charts are not corrected; the light lists and notices to mariners never received. The time furnished will be that of the Naval Observatory, the time signal that denoting Washington noon. As everything will be referred to the meridian of Washington, no complications can arise. The reliability of this information will certainly be strengthened by passing through such an office, the reputation of naval work furnishes sufficient guarantee of that fact. The assistants proposed are to board and obtain from each incoming ocean vessel such data as may be deemed of importance by the Bureau; they will glean from the officers and log-books all matters relating to the routes taken, winds, weather, currents, storms, icebergs, limits of Gulf stream and other phenomena, which when collected and prepared for general use by the Hydrographic office will receive the approbation of those who best know its usefulness. By personal solicitation, data can be obtained which would otherwise be lost, data of great importance which enters into everything pertaining to the sea. How much information that appears each day in the newspapers would appear if it were not for the zeal displayed by the reporters; it is now proposed that a little of such zeal shall be utilized for the benefit of the navy and merchant

marine. The result can even now be foretold by comparing this proposition with the benefits and success following the zeal displayed in other work performed by the navy.

As the army furnishes for the benefit of the country the weather reports, so the navy could furnish time and the valuable hydrographic data proposed in this article, which will be received with as great favor, and aid the great work of building up the merchant marine.

The benefits arising from this proceeding will eventually be of incalculable value to the navy. That time and aids to navigation are furnished is a matter of great importance to the merchant marine, but the fact that the navy is furnishing them for its benefit will show that its interests are in the hands of a branch of the service keenly appreciating its necessities and working for its advancement; show that its welfare is intimately connected with that of the navy, and the interest taken and the work done will be returned in the way most desired, the building up of the navy. When the Chambers of Commerce, the Boards of Trade and Underwriters, backed by the shipping interests of the country, demand a navy, the people will then see that this branch of the public service is one of the great essentials to the prosperity of the merchant marine, and the navy will be built; that protection that capital demands will be assured, and that intimate relation with the merchant marine on which our life and prosperity depend, will then exist; the bond of union will grow stronger each year, until the sails of our merchant marine shall whiten every sea, and a navy commensurate with such a powerful nation shall afford protection in every port.

PROFESSIONAL NOTES.

ON EXPLOSIVES.

Explosive Gelatine.*

For more than a decade there has existed in Europe an active rivalry between the advocates of Nobel's dynamite and Abel's gun cotton as a military explosive. While Austria, France, and Russia have adopted dynamite almost exclusively, England uses compressed gun cotton only. In Austria, owing to the active efforts of Lenk and others in favor of gun cotton, the decision to introduce dynamite into the regular armament of her troops was reached only after long trials and a very searching inquiry. The reasons which led to this decision were, (1) That as dynamite was made in Austria for industrial purposes it could be readily purchased, while it would be necessary either to import gun cotton from England or construct very expensive works for its manufacture if it were to be used ; (2) Dynamite costs less than gun cotton ; (3) Dynamite being mealy, can be used in any shape when wanted *for service*, while it can be readily bought or exchanged, in convenient form and quantities. As gun cotton on the contrary is rigid, it is impossible to alter its shape from that which it possesses, to adapt it to any other purpose than that for which it was originally designed.

When this subject was under consideration the Austrian committee failed to take into account the effects of water upon the permanency of dynamite, or the effects of projectiles in passing through it, or of the general conditions under which it loses its nitro-glycerine by exudation. They also ignored the fact that compressed gun cotton explodes through the action of a powerful fulminate, even when saturated with water, and that when in this condition it is insensitive to fire or to the impact of projectiles fired even at short distances.

Having adopted dynamite as the military explosive, and having decided to purchase it instead of making it, the committee next proceeded to investigate the properties of the explosive more fully, in order to determine what qualities the article to be bought should possess and what tests it should satisfy. While working on this problem various dynamites were prepared, among others Nobel's cellulose dynamite, which was found to be insensitive to the shocks of projectiles when it was moistened with 15 to 20 per cent. of water, but which was abandoned because the nitro-glycerine exuded from it on the least application of pressure ; and gun cotton dynamite, which seemed to possess all the desired requisites. This last, however, was found to be so difficult to

* Translated from *Études sur la Gélatine explosive* by Paul Barbe, with additional notes. Barbe's work is a resumé of Capt. Hess's paper, *vide* Proceedings Naval Institute, Vol. V., p. 24.

manufacture on a large scale that it also was abandoned except for use in fuzes for detonating frozen dynamite.

At this time Nobel brought to the notice of the committee his new explosive called explosive gelatine, and they were so favorably inclined to it that they subjected it to a series of very exhaustive trials, which demonstrated its extreme fitness as a military explosive, since it is easily made, is extremely stable, very powerful, readily molded, perfectly insensitive to blows, friction, the greatest pressure and the shock of projectiles, and with difficulty exploded by ordinary exploders.

The methods by which this explosive may be made have been described by Prof. Munroe.* Of these methods the one adopted in practice is that of dissolving the collodion cellulose directly in the nitro-glycerine, to which camphor has been added, by the aid of the heat of a water-bath, and this process is used at the Torpedo Station, a quantity being made there in 1880 in which 10 lbs. 9 oz. of nitro-glycerine, 14 oz. of soluble gun cotton, and 7.6 oz. of camphor were used. The plain gelatine had, therefore, the percentage composition of 92.35 per cent. of nitro-glycerine and 7.65 per cent. of gun cotton, while the camphorated gelatine consisted of 96 per cent. of plain gelatine and 4 per cent. of camphor. In making this explosive gelatine the camphor was mixed with the nitro-glycerine, which readily dissolved it, and the mixture was heated in the water-bath to 80° C., when the gun cotton, carefully picked and carded, was added and stirred in. Care was taken not to heat too high or too long, as the nitro-glycerine decomposes at 100°. The cotton too was added all at once, as the mass was found to gelatinize so quickly that no cotton could be added after the first lot was stirred in. Since this time considerable quantities have been made at the station with complete success, and while it has only been used for experimental purposes, its adoption into the services is only a question of time.

Although at the Torpedo Station it has been found that explosive gelatine may be successfully exploded by a detonator containing 35 grams of fulminating mercury, and that a detonator of compressed gun cotton never failed to explode it, yet the committee found such great difficulty in firing it completely that they were led to invent a special fuze for this purpose. Having found that exploders containing 2 grams of fulminating mercury, cartridges of compressed gun cotton, or a fuze of gun cotton with 75 per cent. nitro-glycerine, failed to explode explosive gelatine with certainty and completeness, they set about the improvement of the last-named fuze. On examination they found, as Champion and Pellet have pointed out, that gun cotton fibres are very unequally acted upon in the usual process for making gun cotton. It was found, for instance, that a cartridge of Abel's compressed gun cotton contains every variety of nitrified cotton from the trinitrocellulose to pure cellulose, and that these inequalities existed to a greater extent in the gun cotton prepared at Kirtenberg after Lenk's method. Therefore the chemists Siersch and Roth gave up these methods and employed Girard's, in which the cotton is first reduced to a fine soft powder by treatment with dilute sulphuric acid, after which it is subjected to nitrification. They thus obtained a gun cotton whose explosive force and chemical reactions indicated it to be a nitrocellulose of a

*Proc. Naval Inst., Vol. V., p. 22.

high order. This special gun cotton, called nitro-hydrocellulose, is a pulverulent, mealy body, soft to the touch, and which when examined by the microscope still shows the original structure of the cotton. It absorbs and retains in its pores less nitro-glycerine than Abel's pulverized gun cotton, but it shows no tendency to produce explosive gelatine when thus mixed.

A mixture of 60 parts of nitro-glycerine and 40 parts of nitro-hydrocellulose was adopted as the normal composition of the fuze sought. This mixture can be given a greater density than one made with Abel's gun cotton and nitro-glycerine, so that 20 grams of it can be used in military fuze cases which will not hold more than 15 or 17 grams of the other.

Nobel's gelatine prepared as above described with 10 per cent. of gun cotton and with 4 per cent. of camphor added to it, is an elastic, transparent and light yellow solid; density 1.6. It may be cut and subjected to a pressure of 22,000 lbs. per square inch, and preserved at temperatures of 50° to 60° C. (122° to 160° F.) without exuding any nitro-glycerine. In contact with fire it burns quietly and behaves like dynamite; it has been exposed for eight consecutive days to a temperature of 70° C. (158° F.) without showing any traces of decomposition. A sample of several grams was placed on a watch-crystal and heated six or seven hours daily for two months, after which time about one-half of the camphor and a small quantity of the nitro-glycerine were found to have been evaporated. The conditions of this experiment were peculiarly favorable for the evaporation of the camphor, which was not nevertheless complete. This can be ascribed to the gelatinous condition of the body, which thereby prevents the vaporization of the bodies it holds in solution.

When pure gelatine is slowly and gradually heated it explodes at 240° C. (464° F.); the same result follows if suddenly exposed to this temperature. If it contains 4 per cent. of camphor it does not explode at the exploding point of gunpowder, 300° or 330° C. (572° to 626° F.). If the temperature is raised still higher it gives off sparks and burns quietly. The same result is obtained when it contains more than 4 per cent. of camphor. If the temperature is raised suddenly to a very high degree it can be made to explode, but in default of instruments this degree could not be measured. This new explosive can therefore sustain very powerful mechanical blows, since before it can be exploded it requires a relatively extremely high temperature. Its physical condition and want of porosity contribute to make its detonation difficult, consequently the quantity of heat necessary to insure the explosion of the mass should be very great. This explains why gelatine resists blows better than normal dynamite.

Explosive gelatine with or without camphor takes a milky appearance after prolonged exposure in water, without sensibly increasing in weight. When dried it resumes its ordinary appearance, but the water in which it was immersed shows that the mass has lost some of its camphor and nitro-glycerine. These experiments show that explosive gelatine can be transported and kept in water, since the effect of water is only on the surface. After a small quantity of the camphor and nitro-glycerine has been dissolved in the liquid the gun cotton alone remains, which forms a coating, thereby preventing any further permeation of the water through the mass.

In order to study the effect of heat on the new explosive, 20 grams of gelatine with 4 per cent. of camphor were placed in one eprouvette, and a like quantity of nitro-hydrocellulose impregnated with nitro-glycerine in the other. The eprouvettes were exposed to a constant temperature of 70° C. (158° F.) Nitrous fumes were evolved from the nitro-hydrocellulose forty-eight hours after the commencement of the experiment, and from the gelatine seven days after heating it. Since normal dynamite often evolves nitrous fumes when heated to 70° C., we can assert that the new explosive and the fuze composition intended for it offer as much security as it, and we know that the military committee has preserved dynamite in magazines for more than nine years without its showing any trace of decomposition.

Since camphor belongs to the family of turpentine oils, it is well to be assured that it will not ozonize the air like the others, as the ozone might in time decompose the nitro-glycerine. To determine this three balloons were carefully selected, each of a capacity of two litres. The first contained several drops of turpentine, the second 10 grams of camphor, and the third only air. A piece of paper impregnated with iodide of potassium and starch was suspended by a platinum wire and inserted in each of the three balloons. In the course of fifteen minutes the paper in the turpentine balloon began to color and was deep blue at the end of one hour. The paper in the other two balloons colored slowly and uniformly after exposure for three days, the discoloration being due, in both cases, to the ozone normally in the air. We can therefore conclude that camphor does not ozonize the atmosphere.

Explosive gelatine, with or without camphor, resists cold better than nitro-glycerine and silicious dynamite. When frozen it becomes more sensitive to blows than before, which proves the influence of its physical condition on its sensitiveness. It is melted much easier than dynamite and without exuda ion. In detonating, explosive gelatine produces less smoke than dynamite and gives a sharper report.

Record of Experiments.

These experiments were made to determine:

I. What would be the effect of a ball fired from a distance of 25 metres upon the gelatine, either soft or frozen, containing different proportions of camphor, or after having been exposed to a temperature of 30°–40° C. for several days.

II. The comparative destructive effect of gelatine and dynamite upon wooden beams and iron plates.

III. The action of water upon gelatine.

IV. The effect of the explosion of one charge upon others in the vicinity.

V. The difference between the new and old fuzes.

VI. The resistance of the gelatine to the blows of a dynamometer hammer.

I. *Effect of Projectiles.* The gelatine was placed in a box of sheet iron, 4 mm. thick, against a 10-mm. plate of iron, with wood backing. The shots were fired from a Werndl gun at a distance of 25 metres. Four shots were fired into soft gelatine, 4 per cent. camphor, with the same results—no explosion, no inflammation. The shots in the rebound knocked off the lid of the box, the gelatine was scattered, but gathered and replaced. The fifth shot was into gelatine with but

1 per cent. camphor, with the same result. The iron plate was now removed that the effect of shots fired in rapid succession upon the same charge might be observed. Shots 6 and 7 were fired almost simultaneously; the tracks of the bullets coincided, and it may be assumed that the same particles of the charge were successively struck by the two projectiles. There was no explosion nor inflammation, but the box was rendered unserviceable. A new box having been substituted, shots 8, 9, 10 and 11 were fired, the last two almost simultaneously, with no difference in the results. Shots 12 and 13 fired rapidly into the same material were followed by a small local explosion. About five-sixths of the gelatine was recovered; and examination of the wooden backing showed that the explosion had been very insignificant and of no effect, while all the material lost had not been detonated.

The firing was then continued against frozen gelatine, the iron plate having been replaced. Shot No. 14 into gelatine with 4 per cent. of camphor produced an explosion by which the target was demolished. Shot No. 15 into gelatine with 1 per cent of camphor, the iron plate having been removed, produced an imperfect explosion. A thin wooden plank having been placed in front of the box, shot No. 16 was fired with no explosion. More than 400 shots were fired in the same manner under different circumstances against soft gelatine with either 1 or 4 per cent. of camphor, and against frozen gelatine with 2 or 4 per cent. of camphor, without causing any explosion.

From these the following conclusions may be drawn:

a. Camphorated explosive gelatine resists the shock of projectiles perfectly, provided it is not frozen, even under the most unfavorable conditions, since it was struck normally when against an iron plate.

b. It becomes sensitive when frozen, and can then be exploded by the shock of projectiles.

c. A plank of wood interposed between the case containing frozen gelatine and the projectile will be sufficient to prevent its explosion.

d. When the gelatine is supported by wood instead of iron it is insensitive to repeated shocks from projectiles, and seems to be perfectly secure, provided it contains 2 per cent. of camphor.

e. Under the last conditions and with not less than 2 per cent. of camphor, frozen gelatine also resists the shock of projectiles.

It remains to be seen if the camphor can be easily evaporated from the gelatine and so allow it to become sensitive.

Gelatine with 4 and 1 per cent. of camphor in parallelopipeds 26 mm. thick was placed upon the surface of a sieve provided with means for renewing the surrounding air, exposed for forty-eight hours to a temperature of 40° C. (104° F.) and then tried. Shot No. 17 fired into the above gelatine with 4 per cent. of camphor with an iron backing produced no inflammation and no explosion. Shots Nos. 18, 19 and 20 fired against the above gelatine with one per cent. of camphor, iron backing, no explosion. The loss of camphor by evaporization under ordinary temperatures does not apparently diminish the insensitiveness of the explosive. Moreover, it will always be possible to put enough camphor into the gelatine to be certain that, after evaporation, there will be at least 1 per cent. in the mass.

Shot No. 21 fired against ordinary gelatine, without camphor, supported by wood—explosion and complete destruction of the target. This may be regarded as proof positive of the previous experiments.

II. *Destruction of Beams by Gelatine.* The breaking effect upon wooden beams affords a sure method of determining the powers of different explosives; the Committee therefore used a sound spruce beam, 220×32×32 cm., supported on two beams 160 cm. apart. The explosive, in a case 32 cm. long and twice as broad as deep, was placed on top of the beam and fired by means of a fuze. As the tests were to be comparative the best dynamite was necessary; this was made, using 72 per cent. of the best quality of nitro-glycerine and carefully selected sand. It was tested by means of its crushing effect upon leaden cylinders; ordinary dynamite reduced them from 20 to 8 and 13 mm., while dynamite so prepared reduced them to 6.8, 7.2 and 7.6 mm.; it was therefore of a superior quality. The experiments resulted as follows:

1. 780 grams soft dynamite, with ordinary fuze of gun cotton saturated with 75 per cent. nitro-glycerine and a capsule of one gram of fulminate—fracture complete.
2. 610 grams soft gelatine, 4 per cent. camphor, with new fuze of 30 grams nitro-hydrocellulose—fracture complete.
3. 560 grams of the same with same fuze; beam 189 cm., space between supports 126 cm.—rupture complete.
4. 560 grams soft dynamite with new fuze; beam as in 3—fracture complete.
5. 560 grams soft dynamite with ordinary fuze; beam as in 3—almost fractured.

The fourth and fifth trials were made to ascertain the effect of the different fuzes. The effects were in reality but little different, and it may be said that 560 grams is the minimum charge of this quality of superior dynamite, while it would not do to use less than 780 grams of ordinary dynamite. These experiments show that characterizing the explosive force of the superior dynamite by 5, that of ordinary dynamite should be 4; and that 4 per cent. camphorated gelatine is certainly much stronger than the superior dynamite, and for equal weights of charges exceeds ordinary dynamite by more than 25 per cent.

Destruction of Iron Plates. These were 16×16 cm. or 16×32 cm. and from 9 to 40 mm. thick. The charges were inclosed in parchment paper, those of dynamite in cylinders, those of gelatine in prisms, and were 21 cm. long to prevent the fuzes having any effect upon the plates. The only fuze used contained 20 grams of the composition in the usual tin case. The charges were placed in the center of the plates, which were supported by pieces of wood 25 cm. apart; they projected about 5 cm. beyond the edge, and to this end the fuze was attached. The charge of dynamite being cylindrical was not in absolute contact except on its periphery, and in order to make them comparable, the charges of gelatine were arranged with one edge of the prism in contact with the plate. This was thought to be rather disadvantageous than otherwise to the latter. That part of the charge which projected beyond the plate has been neglected in the weights given below. To find the entire weight consumed

the figures given must be multiplied by $\frac{4}{3}$ and the weight of the fuze then added. In these trials one gram of fulminate was used for the fuze charge with the superior dynamite. Four trials with 100 grams of 4 per cent. camphorated gelatine were made; in each case the fracture was complete. Nos. 5, 6, 7, and 8; 100 grams dynamite; complete fracture in 5 and 8; in 6 and 7 the plates were split and bent. Nos. 9, 10, 11, 12; 80 grams gelatine. Fracture in 9 and 10. In 12 a piece under the charge was driven out. In 11 the plate acted as in 6 and 7; from which it will be seen that while 100 grams of gelatine were necessary to insure fracture, 80 grams of it had the same effect as 100 grams of superior dynamite, an advantage of 25 per cent. Nos. 13 and 14; 100 grams frozen gelatine—complete fracture. Not having more frozen gelatine the trials with 80 grams were omitted, but it may be taken for granted it is at least as powerful as soft superior dynamite.

The experiments were continued with plates of iron 26 mm. thick. Nos. 15, 16 and 17; 120 grams of gelatine. The plates were considerably bent and split in 15 and 16—complete fracture in 17. Nos. 18, 19, and 20; 160 grams of superior dynamite. Complete fracture in 18; bent and split, in 19 and 20. Nos. 21 and 22; 160 grams of gelatine—complete fracture. The experiments demonstrate that if the effect of the dynamite be represented by 100, that of the gelatine would be 125, and that 160 grams is the minimum charge for breaking this plate with certainty. The trials were continued with plates of 40 mm., but it is well to note that while the plates of 13 and 26 mm. were fibrous, those of 40 mm. were of granular iron and therefore of less resistance. Nos. 23 and 24; 160 grams of gelatine—complete fracture. Nos. 25 and 26; 190 grams of superior dynamite; complete fracture in No. 25, partial fracture in No. 26, showing the same difference in the relative force.

In order to be certain whether frozen gelatine in very long packages could be entirely exploded, it was made into charges 63 cm. long and 16×16 cm. cross section, weighing 190 grams. The fuzes were also frozen, having been in a freezing mixture for ten days together with the gelatine to be tested. Plates of 16 cm. were used, the supports being 10 cm. apart. The space between the supporting beams being less than in the previous experiments, the explosive had a greater resistance to overcome, and therefore the charge was increased to 190 grams. The fuze was attached to the projecting end of the charge and supported by a piece of wood. Nos. 27 and 28—complete fracture. No. 29; the experiment was repeated with 250 grams of superior dynamite; fuze not frozen—complete fracture. We thus find the same proportion here as before between the weights of the gelatine and the superior dynamite for equal effects. From these experiments on iron plates we conclude that for equal weights, explosive gelatine has 25 per cent. greater force than the best dynamite; that the following charges are necessary to ensure the fracture of the plates:

100	grams for plates	13	millimeters	thick
160	"	26	"	
190	"	40	"	

and that the freezing of gelatine and its fuze does not diminish its explosive force even when elongated to 63 cm.

III. *Effect of Water on Gelatine.* Two cartridges of 133 grams, 21 cm. in length, were placed without any cover in a tank containing 50 hectolitres of water. Two others, also exposed, but in a bag to prevent their being lost, were immersed in the Moldau, secured to a stone in mid-stream. After an exposure of 48 hours, the gelatine containing 4 per cent. of camphor was removed from the water. The surface had become whitish and opaque and covered with a milky coating about 0.5 mm. thick, but no exudation was observed, and the cartridges weighed the same. After a short exposure to the air they resumed their original appearance, and the milky covering disappeared. The experiment against iron plates was then repeated with some of this gelatine, the fuzes used not having been wet. Nos. 30 and 31; 100 grams of gelatine; plates of 13 mm.—completely broken. Explosive gelatine therefore does not seem to lose any of its force by prolonged contact with water, and always has a force equal at least to that of superior dynamite.

IV. *The Effect of Shocks transmitted by Neighboring Explosives.* These experiments were made to ascertain if explosive gelatine was less sensitive than dynamite to the shocks of neighboring explosives. The charges were cylindrical in shape, 8 cm. in diameter, 16 cm. long, and weighed 1 kilo. each; the usual fuze was used and the charges were tied to iron plates. No. 32; charges of gelatine with 5 per cent. camphor, 25 cm. apart. The ignited charge exploded and broke the plate, while the other charge was scattered but not exploded. No. 33; charges of ordinary dynamite, 35 cm. apart. Both charges exploded when one was ignited and both plates were broken. It follows that explosive gelatine is less sensitive to shock than ordinary dynamite.

V. *Experiments with the New Fuze.* Experiments were made by the Austrian committee, which showed that the new fuze is the only one which will detonate with certainty explosive gelatine and develop its full force. Some of the fuzes were composed of from 15 to 17 grams of Lenk's gun cotton impregnated with 75 per cent. nitro-glycerine; others of from 19 to 20 grams of nitro-hydrocellulose impregnated with 60 per cent. nitro-glycerine They were in tin cases, with one gram fulminate placed in the cover, and were fired upon rectangular iron plates 5, 6 and 7 mm. thick, resting upon wooden beams.

No. 34; plate of 5 mm.; new fuze. The plate was pierced with a single circular hole, like a rivet hole, the diameter of the cylinder.

No. 35; plate of 5 mm.; old fuze. The plate received an elliptical indentation and crack and was considerably bent, and could easily have been broken in two pieces. Less force, and above all less suddenness, was indicated as compared with No. 34.

No. 36; plate of 5 mm.; old fuze. Plate split and bent, but not broken.

No. 37; plate of 6 mm.; new fuze. Plate pierced with a neat round hole.

No. 38; plate of 9 mm.; new fuze. Plate pierced with an elliptical hole. This shows that the new fuze has the same effect on plates of 9 mm. as the old fuze on plates of 5 mm. It is therefore superior and obtains from explosives all the force they possess. The old composition is also unsatisfactory because, from want of uniformity in the gun cotton, a portion of it gelatinizes in contact with the nitro-glycerine, forming small lumps which diminish the suddenness of the explosion.

Frozen fuzes were next compared with soft fuzes, each containing 30 grams composition.

Nos. 39 and 40; plate of 9 mm.; new fuze, frozen. The iron was considerably cracked.

Nos. 41 and 42; plate of 9 mm.; new fuze, not frozen. The plate was neatly pierced. Frozen fuzes therefore appear to have less effect than fuzes not frozen.

VI. *Effects from the Hammer of a Dynamometer.* Dynamite imbedded in silica behind planks was exploded by a projectile fired at 1000 paces, while the same projectile had no effect on the gelatine even when supported by an iron plate. These figures clearly indicate that camphorated gelatine is much more insensitive to blows than normal dynamite. The experiments with the hammer do not show any regularity in their results and the details are omitted. They should be repeated. Still we have found that dynamite explodes from the shock of a blow of .45 to 1 kilogrammeter, while the force of the hammer must exceed 2.5 kilogrammeters to explode gelatine containing from 1 to 10 per cent. of camphor. From these facts we conclude that camphorated gelatine may be safely used for charging shells, though direct experiments alone can decide this with certainty.

Resumé.

An explosive suitable to military purposes must satisfy the following requirements:

a. The greatest force and suddenness for unit weight and volume.

b. Comparative insensitiveness to blows and to the shocks of neighboring explosives; and yet enough sensitiveness to be exploded by an easily made fuze.

c. Moderately inflammable; and explosion should not follow too quickly after flame has been applied to it.

d. Stability under the varying conditions of storage and transportation in all seasons.

e. Of easy manufacture by inexpensive plant.

Upon this basis the following comparisons of dynamite, compressed gun cotton with 15 per cent. water, and camphorated gelatine, are made:

a. Force. The foregoing experiments show, the density of dry compressed gun cotton being 1, with about 15 per cent. water the volume does not change, but the density becomes 1.16. In this state its force for equal weight is decidedly inferior to that of ordinary dynamite. Explosive gelatine with 4 per cent. camphor has for equal volumes over 25 per cent. more force than the best dynamite. Gelatine has therefore for equal weights 25 per cent. greater force than wet gun cotton and 75 per cent. greater force for equal volumes. The advantages gained are obvious; for the transportation of a given amount of explosive force fewer horses and wagons will be required; for the storing, smaller, less expensive, and more easily sheltered magazines may be used. For the defense of railroads, for use in torpedoes and shells, explosive gelatine will be especially valuable, and on account of its greater density and power far superior to either dynamite or compressed gun cotton.

b. Resistance to Shocks. The addition of 4 per cent. of camphor to gelatine decreases its sensitiveness in about the same proportion that that of gun cotton is diminished by adding 15 per cent. of water. Recent experiments in England demonstrate that entire lines of torpedoes containing gun cotton can be destroyed by countermines of the same material. It is well to notice that compressed gun cotton, containing 15 per cent. of water, can be completely exploded by a fuze of gun cotton, while the experiments have shown that this fuze will not detonate explosive gelatine. But the insensitiveness of gelatine is increased according to the increase in the percentage of camphor, hence it will be possible so to load submarine mines with the new explosive as to defy the attacks of countermines loaded with compressed gun cotton.

In consideration of its insensitiveness, gelatine seems to be a convenient explosive for loading shells. When shells are loaded with dynamite it is necessary to reduce the percentage of nitro-glycerine in the dynamite to 50 per cent. in order to avoid explosion in the chamber of the gun. This would not be necessary with gelatine, and its force need not be diminished. When shells are now fired against the armor of ships they explode without effect, so that solid shot only are used. But with the new explosive, so insensitive and powerful, shells may come into use again. They may be provided with a massive head, and their explosion after penetrating would produce considerable effect.

But what fuze will be used? May not this fuze be too sensitive? Would not its presence vitiate all the advantages gained by the insensitiveness of the gelatine? This also applies to torpedo charges, for although neighboring explosions have no effect on the gelatine, yet they might affect its fuze. Experiments must decide this. At present it seems certain that its gelatinous consistency and elasticity preserve it from the shocks of neighboring explosions. It might be possible to so arrange a fuze in a special case that it would not be affected by neighboring explosions. When frozen it loses a little of its insensitiveness, but it is certain that the new explosive is as insensitive to the shock of projectiles as wet gun cotton, and much more so than ordinary dynamite.

c. Effect of Flame. It is difficult to inflame wet gun cotton, it must be dried first. Gelatine on the contrary burns in contact with flame as easily as, and in the same way as, dynamite. It is probable that gelatine, like dry gun cotton, will explode after being set on fire, if in large masses. Since gelatine is unaffected by water, it may, perhaps, be stored in barrels partly filled with water. It will then be as safe as wet gun cotton, and superior to ordinary dynamite.

d. Stability.—In reference to explosive gelatine it is necessary to consider if its camphor is apt to evaporate, and if the nitro-glycerine and gun cotton of which it is formed is likely to be affected by long storage or by transportation. These experiments have demonstrated that even under the most unfavorable conditions the loss of camphor by volatilisation is not sufficient to materially diminish its insensitiveness; moreover, it would not be very inconvenient to arrange the cases so as to prevent this action of the air. As it is, plain gelatine, even without any camphor, resists shocks of the hammer of a dynamometer infinitely better than dynamite. The experiments also show that gelatine is at least as stable, chemically, as dynamite, and that the camphor does not modify this property. Every explosive made of nitro-glycerine compounds requires above all that the nitro-glycerine should be carefully made.

We do not know how much longer it will be thought necessary to subject this new explosive to tests. But from the very first appearance of this new explosive we have erred in being too timid, and time has shown that they were right who recommended it. All that has been said about the chemical stability of explosive gelatine applies also to the new fuze, which is otherwise as convenient as the one actually adopted in the Austrian army.

e. Effect of Water. As water appears to have no effect on explosive gelatine, it may be mixed with water for security in transportation. Gun cotton cannot be left in water, as it becomes impregnated to such an extent that its explosion is impossible; on the other hand, it is extremely difficult to keep it at a proper degree of humidity. Dynamite deteriorates if left in water for a long time. Here then is another proof of the superiority of the new explosive over the other two.

f. Manufacture and Sale. Nitro-glycerine compounds have supplanted gun cotton as an explosive for industrial purposes on the Continent and even in England. In Austria there is no factory for making compressed gun cotton, so that if the latter is adopted the government will be obliged to build works, or provide for its importation. This inconvenience does not apply to explosive gelatine, although it contains gun cotton, because very little gun cotton is required to convert nitro-glycerine into gelatine, and the existing works are already of sufficient capacity to produce all that may be required.

From all these facts the following conclusions may be drawn: Explosive gelatine is the most powerful explosive used at present; it can be made more or less sensitive at will; it does not explode when struck by a projectile; it can be kept under water; its chemical stability is sufficient, and it can be supplied at a price not exceeding that of Abel's gun cotton.

Although not the ideal military explosive, this explosive gelatine may be said to fulfill all the requisite conditions much better than compressed gun cotton.

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GUM DYNAMITE, OR EXPLOSIVE GELATINE.*

After narrating at length the history of the dynamites, and describing in full the method of manufacture of gum dynamite, and relating Capt. Hess's experiments with it, which have been fully treated of in preceding articles,† M. Moreau considers the effect of cold upon gum dynamite.

It is found, unfortunately, that gum dynamite, like ordinary dynamite, becomes frozen on exposure to cold, and in this state it is more sensitive to blows than when soft. The temperature at which it freezes is $+ 6°$ C. Fortunately, it is easily thawed without the slightest exudation of nitro-glycerine. The freezing does not diminish its force in the least, and, although its sensibility is increased by freezing, it is still less sensitive to blows than wet gun cotton, and, consequently, than ordinary dynamite.

* Abstract of a paper by M. Auguste Moreau, in the *Mémoires de la Société des Ingénieurs Civils*, December, 1880.

† Proc. Nav. Inst., Vol. V. p. 21, and Vol. VII. p. 473.

The method usually employed for thawing it consists in heating it in water baths made from saucepans of zinc, care being taken not to break the cartridges. When these pans are to be repaired they must always be washed with a mixture of alcohol and ether, to remove any particles of dynamite which may have adhered to them accidentally. When large quantities of gum dynamite, or of dynamite, are to be thawed, the process devised by M. Rutimann, engineer in charge of the work at St. Gothard, may be followed. He built double-bottomed wooden boxes, in which he placed a layer of manure covered with sawdust or mulch. On this was a grating covered with cloth, in which the cartridges were put. The heat of fermentation of the manure was generally found sufficient to thaw the cartridges, but when the cold was unusually great, small vessels of hot water, similar to those used in European railway cars, were imbedded in the mass. In thawing dynamite, or gum dynamite, it should be remembered that it is very imprudent ever to bring the cartridges in contact with stoves, boilers, or steam pipes and the like.

On comparing gum dynamite with other explosives we find that it is not only stronger than dynamite No. 1, but singularly enough it is more powerful than nitroglycerine itself. This is explained as follows:* When nitroglycerine explodes the reaction may be represented by the equation

$$2C_3H_5O_3(NO_2)_3=6CO_2+5H_2O+6N+O,$$

by which it is seen that one atom of oxygen is not utilized. In the gum dynamite, 7 to 8 per cent. of gun cotton is added, which is certainly not as powerful as the nitroglycerine whose place it occupies, but it contains two combustible elements, carbon and hydrogen, which combine with this free oxygen. This chemical union consequently disengages heat and does work. This phenomenon has already been observed in glyoxylin, which is about $\frac{1}{8}$ stronger than dynamite No. 1. Instead of an inert siliceous body, which absorbs a notable quantity of heat, being present, the glyoxylin contains combustible bodies which combine with the liberated oxygen. It is on account of the presence of the silica that dynamite No. 1, containing 75 per cent. of nitroglycerine, is only one-half as powerful as pure nitroglycerine instead of three-fourths.

After M. Berthelot we know that the absolute effect of an explosive is generally proportional:

1st. To the quantity of gas developed.

2d. To the quantity of heat which the gas receives.

Dynamite will not produce then but $\frac{3}{4}$ of the gas given by the same weight of nitroglycerine and therefore only $\frac{3}{4}$ of the heat also. In addition this last will be used in heating $\frac{3}{4}$ of gas and $\frac{1}{4}$ of silica. The gas then will not receive but $\frac{3}{4}$ of the heat produced by the dynamite, or $\frac{3}{4}$ of $\frac{3}{4}$ of the quantity which will be furnished by the same weight of nitroglycerine pure. Admitting then, what is sufficiently exact, that the specific heat of the silica is the same as that of the compressed gases, the dynamite will produce $\frac{3}{4}\times\frac{3}{4}\times\frac{3}{4}=\frac{27}{64}=\frac{1}{2}$ (approx.) of the effect of pure nitroglycerine.

In practice it has been found that in rock of medium hardness gum dynamite is not quite one-half more powerful than dynamite No. 1, but in the hardest

* Compare Proc. Nav. Inst., Vol. V., p. 30.

rocks it is fully one-half more powerful. This shows that it is necessary to confine it closely in order to develop its full effect. Water tamping is sufficient to produce this result.

The strength of this explosive has also been compared with that of dynamite No. 1, by the process devised by M. Colladon,* in which the material is exploded in a cavity in a block of lead. In two experiments in which ten grams of each were used, while the gum dynamite enlarged the cavity to 450 cubic centimetres, the dynamite No. 1 only enlarged it to 300, showing again that the gum dynamite is 50 per cent. more powerful.

In comparing the force of different explosives we must take into consideration the densities of each. These are

Gunpowder,	.90 to 1.00
Dynamite, Nos. 2 and 3,	1.45 to 1.55
" No. 1,	1.55 to 1.60
Gum dynamite,	1.58 to 1.60

Gun cotton, compressed, has a density of 1, but when we add 15 per cent. of water, while its volume remains constant, its density is raised to 1.16. In this state the force of an equal weight is sensibly less than that of dynamite No. 1. Gum dynamite possesses then, weight for weight, 50 per cent. more force than wet compressed gun cotton, and only 70 per cent. of the volume.

Mr. MacRoberts has tabulated the weight of each explosive necessary to do a certain amount of work. Taking that done by one gram of gum dynamite as unity, we have:—

1.	gram	of gum dynamite.
1.10	"	nitroglycerine.
1.50	"	dynamite No. 1.
2.15	"	dynamite Nos. 2 and 3.
4.50	"	gunpowder.

As gum dynamite costs in commerce 8 francs a kilogramme, while dynamite No. 1 costs but 6 francs, its use has been objected to on the score of expense, but as it will do fifty per cent. more work it is really as cheap, while if we consider that in blasting a less number of holes have to be bored, and that all other work is reduced in proportion, it is really much more economical. In fact it is found that in using dynamite No. 1 there is a saving of 20 to 40 per cent. in labor and 15 to 25 per cent. in time over blasting powder. With gum dynamite, then, there must be a saving over dynamite No. 1.

M. Moreau then proceeds to cite from the records of the engineers at St. Gothard and Stockholm, and in various mines of Germany and France, results which show the economy resulting from the use of this explosive.

C. E. MUNROE, Prof., U. S. N. A.

* Proc. Nav. Inst., Vol. V. p. 25.

BLASTING GELATINE AND GELATINE-DYNAMITE.*

These new explosives have been tested at the Friedrich mine at Tarnowitz, in hard, compact rock, and it is found that blasting-gelatine is safer, more effective, and, notwithstanding its higher price (fifty per cent. more), it is more economical than ordinary No. 1 dynamite. The gelatine-dynamite is sold at the same price as ordinary No. 1 dynamite, but is, it seems, not likely to replace the latter. It requires a strong detonating cap, containing not less than eight grains of fnlminate of mercury, to develop the full force of explosion, and even then its effect is not greater than that of ordinary dynamite. A series of tests of blasting gelatine in blasting rock, extending over several months, were made at Mansfeld which proved the greater economy of the gelatine as compared with dynamite. In hard rock the saving in expense was one-third; in soft rock it was somewhat less. Blasting gelatine possesses also the advantages of not being so easily frozen as dynamite and of being unaffected by water. *Explosions at the Rhein-Preussen Mine and at Leimbach near Mansfeld have thrown some doubt on the stability of blasting gelatine, as these explosions are said to have been spontaneous.* This, however, has not been clearly established. Blasting-gelatine is the explosive-gelatine or gum dynamite of Nobel containing camphor. Gelatine-dynamite is explosive gelatine mixed with nitrate of potash.—Gun Cotton. It has been definitely proved that this substancc must be kept dry in order to give good results.

C. E. M.

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BULLETIN No. 2, 1881. A cruise along the northern coast of Africa, by Lt. Comdr. H. H. Gorringe, U. S. N.

ARMY AND NAVY GAZETTE.

DEC. 3, 1881. The following extract is taken from a leading article upon the revision of naval uniform. "We believe it is the general opinion in the service that either the so-called 'full dress' or 'undress' [social?] coat should be abolished, keeping only one for all 'dress' purposes, and wearing epaulettes and 'gold-lace trousers' for full dress occasions. A heavy and useless tax is put upon naval officers by making them have the two coats, for on most stations the necessity for full dress seldom or never occurs; the coats lie unused in the cabin drawers or the chest for the whole commission, and are never seen, except when clothes-lines are rigged and the said uniform is displayed for airing purposes, this ceremony often showing, especially in small craft, that the coats, etc., are none the better for keeping. The *first* expense is considerable, and in many instances entirely useless, for officers are but flesh, and their measurements, as years go by, are apt to vary, while their coats remain as at first built, and the consequence is that at a full dress occasion on board a ship, suddenly and unexpectedly called upon, officers do not present that appearance which would lead the spectator to exclaim, 'A thing of beauty is a joy forever.'"

BROAD ARROW.

NOVEMBER 26, 1881. The United States Navy.

"Although the United States naval authorities are still disposed to defer the building of iron-clads until the ship of the future has been decided upon in Europe, they are yet bent upon making vigorous efforts toward constructing a fleet of swift unarmored cruisers. As with ourselves, however, the money difficulty is a serious one, and they have first to persuade Congress of the necessity of the case before they can construct the modest number of forty-one unarmored vessels, which they have reported should be built. Should this programme be appproved, the United States navy will then consist of sixty-two ships of all classes. Of the forty-one vessels which it is proposed to lay down, two are of 5300 tons and able to steam fifteen knots, six of 4200 tons to steam fourteen knots, thirteen of 3500 tons to steam thirteen knots, and twenty gunboats of 770 tons each to steam ten knots an hour. It is recommended by the Naval Advisory Board that all but the gunboats should be built of steel, covered with wood, and sheathed with copper. The gunboats would be entirely of wood. All the cruisers are to be full rigged, and capable of sailing independently of their steam power; and they are designed to carry enough coals for six days' full steaming. It is estimated that this programme will cost $31,000,000, and occupy eight years. The object of such a fleet as this is evidently to harass, and, if possible, destroy the commerce of an enemy. It can scarcely be planned with a view solely to the defence of her own commerce, as

the United States has very little left. In 1874 she had only 1,410,000 tons of merchant shipping, and now the tonnage is probably even less. It was in that year that Admiral Porter, in his evidence before the Committee of Congress on the decline of commerce, said that 'in case of war with either France or Great Britain, the American power would be exerted in cutting up their commerce.' The present relations between these countries and the United States are all that could be desired, and we trust that nothing will ever occur to disturb the cordiality that exists between our cousins across the Atlantic and ourselves. But it would be unwise for us to reckon upon our present friendship as a permanent factor in the consideration of the precautions with which we should insure the safety of our mercantile marine, and the maintenance of our large ocean carrying trade. Admiral Porter in the course of the evidence from which we have already quoted, said, 'Great Britain could not stand a war six months with the fleet of ships we could send out after her vessels. They would break her up root and branch, and that kind of warfare would be more likely to bring about peace than fighting with iron-clads or heavy war vessels.' If America could do this seven years ago, what would she not be able to do with the proposed unarmored fleet of high powered, swift steel cruisers? Speaking on the subject in 1875, Sir Thomas Brassey—no mean authority—said, 'Our strength in unarmored cruisers is still in excess of that of any other naval power. For every 1000 tons of merchant shipping our fleet of cruisers contains 32 tons, while the proportion which the tonnage of the unarmored cruisers bears to every 1000 tons of merchant shipping is in the French navy 14 tons, and in the German navy 4 tons.' At that time the corresponding proportion of United States cruisers was less than that of France. Since 1875 we have largely increased our unarmored fleet, especially in the item of swift steel cruisers, so that our position is better in that respect now than it was then. Besides which it must be remembered that since 1875 very few sailing ships have been built for the mercantile marine, while during the same time many of our sailing ships have been lost. These latter have been replaced by steamers, and more than replaced, for the steam tonnage built during the past three years is equal to that of the six years previous. Hence our mercantile navy is better able to take care of itself than it was, and our war cruisers are more numerous and better equipped. The programme of the United States Naval Advisory Board need not therefore terrify us even if it is accepted by Congress, which, considering the estimated cost, is doubtful. It is well, however, that the Admiralty should take a note of the speed which the Americans propose to give to their largest ships, as we fear our recently constructed cruisers have been somewhat deficient in that respect."

Cruiser Warfare.

Commodore L. P. Semetchkin, who had control of the Russian cruiser operations in America, in 1878, delivered a lecture recently upon this subject, in St. Petersburg.

"In his opinion the cruiser question was a State question. Russia's rival and enemy—England—was impregnable, so far as her navy was concerned—no European power could surpass her in that; but she could be both crippled and ruined by a regular series of cruiser attacks against her mercantile marine, her Indian coast, and her colonial possessions. Russian cruisers need not be very numerous, but they must be swift, carry extremely heavy armaments, and be furnished with a large capacity for the stowage of coal. They should be trained to act singly, like a Cossack picket, to look for no support, and to dispense with any base. The best cruising grounds he considered to be the Norwegian coast, the Atlantic and Pacific seaboards of the United States, both sides of South America, and, above all, the seas. He would have a cruiser bureau attached to the Russian Admiralty, where a careful record should be kept of the actual condition of the English marine, and the best routes for privateers, and whence, on an outbreak of war, every information should be forthcoming for the use of the cruiser captains. Maps showing the best cruising grounds were exhibited; these had been intended for the use of the cruisers in 1878."

DECEMBER 10th.

"The American Advisory Board on the Reorganization of the Navy, in their report just published, is of the opinion that ironclads should be built for the American navy, but not until after the thirty-eight unarmored cruisers, five steel 2000 ton rams, five torpedo gunboats, ten cruising torpedo boats, and ten harbor torpedo boats, which, at an estimated cost of twenty-nine to thirty-one million dollars, they recommend should be put in hand. As they calculate this programme will occupy eight years in being carried out, it is evident that the United States are in no great hurry for ironclads. One would have thought that their recent inability to back their views and intentions with regard to South American complications with a naval force, would have brought home forcibly to their perceptions that an ironclad fleet, at least equal to the combined fleets of the South American Republics, was a necessity for a power taking such a view of its duties and responsibilities as the United States has recently done. Perhaps the American people are also of this opinion, but the Naval Advisory Board is unable to suggest a type of ironclad which is likely to remain in fashion up to the time the vessel is ready for sea. Hence, under these circumstances, they do not feel in a position to advise any ironclads at all. The Advisory Board looks upon an ironclad ten years old as obsolete; and so in fact she is. But although obsolete, she would not be useless. The Inflexible was designed nearly eight years ago, but we do not suppose that in two years hence she will be a useless vessel; nor do we think that the Devastation, which was designed more than ten years ago, would be refused by the Americans if offered to them. It is true, we are not building Devastations now, simply because we have discovered a better type of ironclad; but we, nevertheless, have an idea that for many years to come, whatever improvements may be made in naval construction and gunnery, the Devastation, Thunder, and Dreadnaught will be able to render a very good account of themselves if required to do so."

CONTEMPORARY REVIEW.

OCTOBER, 1881. The carrying trade of the world.

DECEMBER. Fair trade and free trade.

EDINBURGH REVIEW.

OCTOBER, 1881. The fallacies of fair trade.

ENGINEERING.

OCTOBER 7, 1881. The Jablochkoff system at the Paris Electrical Exhibition. De Meritens accumulating battery and magneto-electric machine.

OCTOBER 14th. The manufacture of projectiles.

In this paper, read before the Iron and Steel Institute, Mr. J. Davidson, of Woolwich arsenal, points out the main features of the manufacture of projectiles in the Royal laboratory. Welsh iron was found to be the best material, but on account of its cost the ordinary mixture is composed of 30 per cent. Welsh iron, 30 per cent. old shell, 20 per cent. old guns, and 20 per cent. scrap. The consumption of iron in ordinary years varies from 5000 to 8000 tons.

Hedges Electric Lamp.

OCTOBER 21st. Modern British Ordnance, a paper read by Colonel Maitland, R. G. F., Superintendant of the Woolwich arsenal, before the Iron and Steel Institute.

In order that guns may be light, powerful and safe, the material from which they are made should possess the following qualities: uniformity, high elastic limit, strength, and capability of elongation, not forgetting cheapness. The wrought iron coils used in the Royal gun factory are made chiefly from wrought scrap. Railway scrap is preferred, and the more bolts the better; a proportion of puddled iron is also used, derived from old cast iron guns of the service.

Blooms of these materials are rolled into flat bars, piled with the scrap inside and the puddled iron outside, and rolled into bars of such section as may be required.

The following is the process adopted of making steel. Suppose a new furnace (Price's patent retort) is ready to our hands. The hearth where the metal has to lie is in the form of a shallow dish, with an incline in every direction towards the tapping hole. To make an impervious bottom to this hearth, fine pure silicious sand is used, so that the smallest crevice may be filled. The furnace having been brought to an intense heat, a thin layer of the prepared sand is spread evenly over the bottom, and subjected for more than an hour to the highest temperature attainable. The sand will now be set or caked. The furnace door is opened, and another layer of sand spread over. This is repeated several times until a depth of from two to three inches is attained. It takes a whole day to make the bottom of a new furnace.

The hearth being ready and a tapping hole made, the furnace is ready to be charged. For a 3-ton ingot the average charge would be 24 cwt. of selected pig with 24 cwt. of scrap steel and 2 cwt. of iron ore. At the end of four hours this will be melted. Then more scrap steel, or wrought iron, as the case may be, is charged hot in portions of about 4 cwt. at a time. This takes 15 to 20 minutes to melt, and gives the furnace time to regain its heat. These supplementary charges are repeated until about 20 cwt. of hot steel scrap or wrought iron has been added to the bath. Care is taken that the proportion of carbon in the melted metal does not get too low before the whole of the charge is put into the furnace. When the charge is all melted, a specimen is taken from the bath and tested for carbon; and more oxygen is supplied, if necessary, by means of iron ore. At this stage about 28 lbs. of ore may be added; and at intervals of fifteen minutes more ore is thrown in, should it be required, and the metal again tested. A specimen taken from the bath, beaten out with a hammer while hot and cooled in water, should hardly show any signs of temper. It should bend over double and behave like soft iron. Another piece cooled without hammering should when hammered show a toughness and softness almost equal to copper.

The metal is now ready for the ferro-manganese, of which 1 to 1½ per cent. is used for making soft steel. It is broken into small pieces and made red hot before being put into the furnace. After a lapse of eight or ten minutes the metal is then tapped.

Analyses of specimens of steel, from four different manufacturers, which have been employed for gun tubes with satisfactory results, give as a mean 0.288 per cent. carbon and .228 per cent. manganese.

October 28th. Lights for lighthouses.

The object of this paper as stated by the author, Mr. J. R. Wigham, is to show that, notwithstanding the superior intensity of the electric light, it will not be found so useful for lighthouse purposes as the quadriform and other gas lights. The result of experiments in England, in 1874, was that in fine weather the electric light was much brighter than the gaslight; in misty weather it was less brilliant than gas, and in foggy weather the gaslight was visible long after the electric light had been obscured. Four electric lights have been set up in England. At one of these lighthouses, Dungeness, the electric light has been discontinued, and oil again used, chiefly because its great glare deceived mariners as to their distance. There is a double objection to the electric light: 1. In fine weather it is misleading to the sailor; he cannot be certain of his distance from it; according to the state of the weather it looks equally bright, whether it be ten miles off or only one. 2. In foggy weather, when a light is specially needed, it is more easily totally obscured by the fog than the gaslights on the triform and quadriform plan now applicable for lighthouses. The original cost of applying the electric light at a lighthouse is more than double that of applying gas or oil, and the annual cost of maintenance is also more than double.

Buss's Tachymeter.

NOVEMBER 18th. Report of the full power trials of the engines of H. M. S. Wrangler class. Griscom's double induction motor.

NOVEMBER 25th. The most advantageous efficiency for steam boilers. Batteries at the Paris Exhibition. Field gun carriages and the strains of recoil, by Mr. H. J. Butter.

The highest velocity of recoil, obtained by dividing the product of the weight of the shot into its initial velocity by the weight of the gun, has been found to be incorrect. This might be true were the recoil of the gun to begin at the same instant with the ignition of the charge; but it has been found that the recoil begins when the projectile leaves, or after it has left, the muzzle. The highest velocity of recoil may then be calculated for pebble powder from the formula $V = \frac{vw}{W}\sqrt{\frac{4}{3}}$ and the energy developed from the formula $E = \frac{V^2 W}{2g}\frac{4}{3}$. The results by this method give a remarkable degree of uniformity when compared with that obtained from the time waves of the curves and areas of the curves of recoil.

Alexander's slip link. Gun cotton.

DECEMBER 23d. Jablochkoff's alternating current generator. Ex-focal light for lighthouses.

Objection having been made to the Wigham gas-burner because gas flames being largely ex-focal, were in consequence of no value to the mariner and therefore wasteful, Mr. Wigham shows by the concurrent testimony of many shipmasters that in thick or foggy weather the ex-focal light is of greatest value, indicating the position of the lighthouse by the loom or glow, when the light itself is invisible.

DECEMBER 30. Jaspar system of electric lighting. De Musanne's electric lamp. Thornycroft's screw propeller and steering gear for torpedo boats.

FRANKLIN INSTITUTE JOURNAL.

OCTOBER, 1881. Experiments on the strength of wrought iron and steel at high temperatures. The proper method of expansion of steam and regulation of the engine. The last experiment (Mar. 19, 1881) with the Perkins machinery of the steam yacht Anthracite.

DECEMBER. Report of the committee on the precautions to be taken to obviate the dangers that may arise from systems of electric lighting.

The committee was composed of Drs. R. E. Rogers, C. M. Cresson, and Isaac Morris, and Messrs. David Brooks, E. A. Scott and E. J. Houston, and from the report the following extracts are made: "That from a careful consideration of the evidence submitted they believe that the use of electricity as an illuminant, as now generally employed, is not attended with any dangers, either to person or property, that cannot be obviated by the adoption of precautions hereinafter set forth. . . . 1st. That the conducting wires leading into and out of the building be suitably insulated throughout their entire extent, both to and from the machine producing the current. 2d. That an inspection be made at suitable intervals to determine whether or not the insulation has been preserved intact. 3d. That conductors formed of numerous short pieces of wire be avoided as far as possible, and that when their use is necessary the joined ends be made as secure as possible by wrapping, so as to prevent short arcs being formed at imperfect junctions, should the joined ends be partially separated from each other. 4th. That the wires be not grounded, that is, no

attempt be made to cause the current to pass back to the machine through the earth, but that a continuous line of wire be provided, through which the current shall so return. 5th. That the ready occurrence of cross contacts and short circuits be avoided. 6th. That the conducting wires be of sufficient size to carry the most powerful current employed without dangerous heating. 7th. To avoid the danger to life from the accidental discharge of the current through the body, the conducting wires should in all cases convenient be placed out of reach, either by choice of locality or by the use of heavy and guarded insulation. 8th. That where lamps of the arc type are used, they be covered with a globe of glass, and that the lower end of such globes be furnished with a cup or pan for retaining any heated fragments."

GIORNALE D'ARTIGLIERIA E GENIO.

JANUARY, 1881. New ordnance in the Spanish navy.

INSTITUTION OF MECHANICAL ENGINEERS.

PROCEEDINGS, AUGUST 1881. The Tyne, as connected with the history of engineering. The progress and development of the marine engine, by Mr. F. C. Marshall.

This paper has had the honor of a reprint in a number of engineering journals, and is of particular interest, as it shows the improvements that have been made in the machinery of merchant and war ships. As to the tabulated results of the economical performance of the machinery given by Mr. Marshall, one is led to think that the horse-power taken is that indicated at the moment the diagrams are taken, and not the average for the day; if this is so, the power should be corrected for the day's run when the coal is taken for the day. The description and plates of the various types of marine engines and boilers, as well as the details of their construction and management, are of particular interest to the engineer; the discussion of the advantages of a forced draft in boilers by which the maximum power may be obtained from the minimum weight of boiler shows that the system has many advocates. The author of the paper favors the use of locomotive boilers or their equivalent, and thinks that the weight of machinery, fuel and water carried has not received that attention which the importance of the subject demands.

In making the following table of the average weight of the machinery, including engines, boilers, water, and all fittings for sea (excluding coal), the power taken is that indicated by the diagrams on the measured mile trial, and is the maximum indicated horse-power, while as a rule the average maximum power developed at sea under ordinary conditions is about 70 per cent. of that developed at the measured mile trial for merchant steamers, and less for naval steamers, which must be considered in making comparisons.

TABLE OF WEIGHTS IN POUNDS PER I. H. P.

Merchant steamers,	480
Royal Navy (English),	360
Engines specially designed for light-draught vessels,	280
Royal Navy ("Polyphemus" class given by Mr. Wright),	180
Modern Locomotive,	140
Torpedo Vessels,	60
Ordinary marine boilers, including water,	196
Locomotive boilers, including water,	60

Iron and steel as constructive material for ships, by Mr. John Price.

The discussion of this subject by men who have built ships of both materials, is of special interest to all who are interested in the constructive material of the new unarmed cruisers proposed by the Advisory Board; it is a clear statement

of how much has been saved by building ships of steel, instead of iron, as well as the increased cost of such a structure. The question whether the wear and tear, as well as the interest on the increased investment, will counterbalance the receipts from the freights due to the greater dead load carried, is ably discussed, and the conclusion reached is, that for some trades, iron ships will pay better than steel at the present price of the latter material, though the advantage is on the side of steel in nearly all cases where full freights are to be obtained. In naval vessels, steel should be the material for framing, plating and beams; in every steel ship it will be advisable to use a certain amount of iron, as the thickness of the material and not its strength will decide the question as to what must be used. It is doubtful if a greater saving than 10 per cent. can be made on the weight of the hull of a ship by using steel instead of iron; both having equal strength, the cost per ton of displacement will be much greater, in material and labor, for steel.

Sir Henry Bessemer made the statement before the Iron and Steel Institute that, up to that time, no steel by the Bessemer or other processes had been made that was uniform in its quality; he went so far as to say that the steel of an ordinary table knife might be hard on one side and soft on the other, but by the introduction of a rotary mixer they were now able to mix the metals so that they would be of uniform quality.—*Engineer*, October 14, 1881.

The Elswick Engine and Ordnance Works, (Sir Wm. Armstrong & Co.).

The system of built-up gun construction is carried out in these works on true mechanical principles. By this system of construction sufficient longitudinal strength is obtained with the maximum circumferential strength; as now built the gun is almost wholly of steel, an inner steel tube about which is wound coils of a steel riband, with the tension adjusted on each successive layer. To give longitudinal strength, steels staves with the ends notched over are placed over the coils of riband steel, then over these staves are firmly fixed steel and two wrought iron bands, which is all the iron used in the construction of the gun. A 6-inch gun has been made on this system, and fired, giving results far surpassing any that have yet been obtained with guns of the same weight; a 10-inch gun is nearly complete.

This number is an exceedingly interesting one to those dealing with the questions of the designing and construction of ships, their motive power and armament.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

Vol. IX., Nos. 10, 11. The Niger table.

A discussion of the means by which this now famous table of lunar distances was constructed. This subject seems fruitful for discussion, as several papers in former numbers of this journal and of the *Revue Maritime* have been devoted to its consideration.

Water-tight compartments and the pumping arrangements of modern men-of-war. The management and machinery of torpedo boats. Relations between the constant dynamo-electric machines. Record and results of the third international Polar conference, held at St. Petersburg, August 1881.

This paper gives a complete account of the scientific work which it is proposed to undertake.

New Gramme regulator for several lamps in continuous circuit. Experimental data in regard to mitrailleuses of large calibre and rapid firing cannon of small calibre. The change in the magnetism of iron ships. Trial of the Russian yacht Livadia. The imperial German flush-deck corvette Marie. The Buonaccorsi propeller. The condition of the Austro-Hungarian merchant marine. Bachman's telemeter. Review of U. S. Naval Institute prize essay for 1881.

No. XII. A summary of the data on compound armor. A simple derivation of the theory of Mercator's chart. Anchor gear on the steamer Helois. Notes on English naval matters. The English monitor Conqueror. The Italian squadron in the year 1880–81. The Russian Naval Academy. Conventional colors for painting the smoke-stacks of the ships of the French navy. Jamin's new modification of the electric lamp. Statistics of the Italian merchant marine. Area of the seas according to the latest calculations.

MITTHEILUNGEN UEBER GEGENSTANDE DES ARTILLERIE UND GENIE-WESENS.

No. X., 1881. The brachy-telescope. Analysis of nitroglycerine. Note on the preservation of wood.

No. XI. Firing experiments at Krupp's factory in 1881. Cannon tubes of steel bronze in Germany, with record of experiments. The purification of gun cotton from decomposition products. Note on the canal between the North and Baltic seas.

No. XII. Explosion of a 16 cm. cannon on the corvette Tornado. Firing tests with gun bronze. Phosphorescent powders. New torpedo depot in Brunshausen.

MONITEUR DE LA FLOTTE.

November 6, 1881. A new torpedo.

A Roumanian engineer has just invented a submarine torpedo boat which is characterized by the power of manœuvring under water for twelve hours without interruption. It can work at a depth of one hundred feet in rivers and from seven to eight hundred feet in the sea; it rises or sinks noiselessly either instantly or progressively, by means of a set of propellers; it is capable of moving in any direction, and it carries a light by which the officers who direct it can see a distance of one hundred and thirty feet. When at the surface of the water it manœuvres like an ordinary armored torpedo boat.

A new type of ship.

The discovery of M. Raoul Pictet consists in a new system of vessel against which the resistance of the water shall be considerably diminished by constructing it in such a manner that it shall pass over the water instead of through it. From mathematical calculations carefully verified, vessels so constructed should attain a speed of from fifty to sixty kilometres an hour. A boat is to be built to test the plan and will be tried upon Lake Geneva.

Marine instruments at the Electrical Exposition.

M. Bisson's electric compass is composed of an ordinary magnetic compass which is placed in such a position on board ship as to be free from local attraction; at the masthead, for instance. The indications which it gives are then transmitted electrically, by a system ingenious, though perhaps complicated, to a needle on the deck or bridge of the vessel; this needle being always parallel to that at the masthead, indicates the magnetic meridian of the place.

M. Bonneau exhibits an apparatus for observing and recording the direction and force of submarine currents; it consists of a sheet brass boat capable of being hermetically closed and weighted so as to be sunk under water. To use it it is immersed to a convenient depth and kept in place by a float; a large keel acts as a rudder and keeps it in the direction of the current, while a screw of known pitch turns with a velocity proportionate to that of the water. The shaft of the screw, inside the boat, makes and breaks at each revolution an electric current which leads by a wire to the registering apparatus whereby the

velocity of the current may easily be determined. To determine at the same time the direction of the current there is in the boat a compass composed of an electro-magnet. The wire for registering the current passes around this magnet in going to a circular groove cut in the bottom of the reservoir of the compass. In this groove is a liquid whose electric conductivity is known, and into it is plunged one of the ends of the wire from the electro-magnet. There is a partition in the groove, and the electric current is obliged to pass through that portion of the liquid between the partition and the wire from the electro-magnet. The length of this section of fluid varies with the direction of the electro-magnet, and, the variation in the current being measured by means of a galvanometer, the angle made by the electro-magnet with the axis of the boat, that is, the direction of the current, may be determined.

NOVEMBER 27th. An electro-motor boat.

A boat twenty feet long, three and a half feet beam, provided with an electromotor, is to be launched at Boulogne, and the owner purposes crossing the channel to Folkestone in it. This experiment will be very interesting, as, if successful, it will be the first instance of a voyage in a vessel driven by electricity.

Submarine Blasting.

Major Lauer, of the Austrian Engineers, has used a new method in removing rocks in the bed of the Danube, at Krems. He placed the charge of dynamite so that it touched the surface of the rock, in a hollow cylinder like a piece of gas-pipe and fired it by electricity. The rock was broken in fragments so small that they were swept away by the force of the current. The method is about forty per cent. cheaper than that formerly employed.

DECEMBER 18th. Dynamose.

"This name is given to a new explosive recently experimented upon in Austria. The composition is not stated, but the experiments showed that in muskets a greater initial velocity was obtained than with powder, with less fouling of the piece."

DECEMBER 25th. The phosphor bronze boat.

"A small boat constructed entirely of phosphor bronze has recently been launched at the Thames; it is thirty-five feet long with six feet beam, and has attained a speed of nearly twelve and a half miles an hour. It was built by the Phosphor Bronze Co. to test the strength of the phosphor bronze sheet and angle pieces before undertaking to construct more important vessels, and in rigidity and absence of vibrations the boat fully realizes their expectations. It is thought that the advantages of an unoxidizable metal will more than counterbalance the increase in the first cost in the construction of vessels."

NEW YORK GENEALOGICAL AND BIOGRAPHICAL RECORD.

JULY, 1880. Commodore Hull and the Constitution.

A sketch of the life of Commo. Isaac Hull, by Gen. Jas. Grant Wilson, in which appears the following: "Hull and Dacres had met before the war and had some conversation in regard to the merits of their respective navies. Professional pride operating on both, led them from generalities to particulars, and at last to speak of what would happen if, in the event of war, their ships, the Constitution and Guerrière, should come into collision. Hull, who was lively and good-humored, laughingly said to the English captain, 'Take care of that ship of yours, if I ever catch her in the Constitution.' Dacres laughed in return, and offered a handsome wager that, if ever they did meet as antagonists, his friend would find out his mistake. Hull refused to bet money, but said he would wager on the issue—a hat. As Dacres, who was wounded in the action I have described, came up the side of the Constitution, the kind-hearted Hull

said, as if addressing a shipmate, 'Dacres, give me your hand, I know you are hurt,' and when the captain offered his sword, Hull added, 'No, no, I will not take a sword from one who knows so well how to use it—but—I'll trouble you for *that hat*.'" A short history of the Constitution is added.

Obituary. Captain Homer Crane Blake, U. S. N.

NINETEENTH CENTURY.

OCTOBER, 1881. Fair trade and free trade.

QUARTERLY REVIEW.

OCTOBER, 1881. Fair trade and British labor.

POPULAR SCIENCE MONTHLY.

NOVEMBER, DECEMBER, 1881. Deterioration of American oyster beds, by Lieutenant Francis Winslow, U. S. N.

In a recent number of *Lippincott's Magazine* appeared an article which logically led to a belief that oyster culture in the United States could, if conducted as in France, be made financially successful. Mr. Winslow in these articles shows that while oyster culture is an expensive and laborious undertaking of doubtful financial success, oyster protection may be easily achieved with but a small expenditure of money. While attached to the U. S. Coast Survey in command of the schooner Palinurus, Mr. Winslow made thorough and exhaustive investigations of the oyster beds in Tangier and Pocomoke sounds and parts of Chesapeake bay during the summers of 1878–79. The results of the work accomplished may be found in the *Report of the Commissioners of Fisheries of Maryland*, 1880; and the Société d'Acclimation of Paris in awarding a medal of honor to Mr. Winslow, atttested to their value in a manner which must be as gratifying to him as it is to the service to which he belongs.

REVISTA GENERAL DE MARINA.

OCTOBER, 1881. Reckoning of time and the choice of an universal prime meridian (continued). Notes on Japan (continued). Mangin's designs of reflectors (translation). The automatic life-saving jacket of Soliani and Martorelli. Explosion on board the Tornado of a gun which had been altered from twenty to sixteen centimeters upon the Palliser system. Theory of cyclones. The corvette Aragon.

NOVEMBER. Review by the Emperor of the German squadron of instruction in the port of Kiel. The Spanish navy. The interior arrangement of ships. Transformation of the merchant marine. The corvette Aragon.

DECEMBER. Height of mounting machine guns (translation). Daltonism (color-blindness) in navigators. Some considerations upon the explosion on board the corvette Tornado. The Spanish navy. A new sounding machine, by Sir William Thompson (translation).

REVUE D'ARTILLERIE.

OCTOBER, 1881. A calculation of the elements of fire when the angle of elevation of the target is considerable, and the application to plunging fire. Theoretic study of shrapnel.

NOVEMBER. The influence upon the range of small arms of the constant diminution in the initial velocities given by metallic cartridges.

"Experience shows that the powder enclosed in metallic cases undergoes in time a certain transformation, and that the initial velocity that a given weight of

powder will impress upon a ball of given weight and determined form diminishes a certain amount each year. From experiments made in France in 1880, on cartridges manufactured there in 1876, which had originally an initial velocity of 450 metres, it appears that this diminution varies between three and a half and four metres a year."

Accordingly, *Chef d'Escadron* J. B. F. Lefevre discusses in this paper the correction in sighting which should be made to compensate for the deterioration of the powder, and in conclusion recommends that the initial velocities of the cartridges of various dates of manufacture should be determined twice a year, and the information sent to those concerned.

The B. L. Armstrong guns. *Notices.* A new explosive for shells.

"Experiments were made in March last, in Russia, with a new style of projectile charged with compressed gun cotton and fulminate of mercury. This composition appears to be able to produce great effect against defences, and at the same time to resist the shock of discharge; not a single projectile exploded prematurely during the experiments.

The parapet against which the shells were fired was covered with wood protected by a 15 cm. steel plate. With a reduced charge the projectile ricocheted on the plate; combining proper charge and angle of elevation, after passing through the sheathing and wood backing, it exploded in the parapet, producing remarkable destructive effects.

The results of these experiments show the possibility of firing shells of this description in the manner indicated and of giving great effectiveness to a curved fire against ships. When the quantity of pyroxyline which can be enclosed in a 28 cm. shell is considered, it is easy to imagine the destruction its explosion would produce on board an enemy's vessel.

REVUE DES DEUX MONDES.

DECEMBER 1, 1881. The war in the Pacific.

RIVISTA MARITTIMA.

OCTOBER, NOVEMBER, 1881. Voyage of the corvette Vettor Pisani. The triremes. The study of continental and maritime geography from a military point of view. Marine boilers. Navigation of the gulf of Siam. Naval tactics. Diary of the exploration of the Rio Negro in Patagonia. Torpedo boats.

DECEMBER. Voyage of the corvette Vettor Pisani. The triremes. The cutting of the isthmus of Corinth. The Gregorini iron works at Lovere. The study of continental and maritime geography from a military point of view. Marine boilers. The navigation of the gulf of Siam. Armored defences. The Polyphemus.

ROYAL GEOGRAPHICAL SOCIETY.

PROCEEDINGS, DECEMBER, 1881. *Geographical Notes.* Visit of the Corwin to Wrangell land. Visit of the Rodgers to Wrangell land. The Arctic cruise of the Alliance. American polar station at Lady Franklin bay. U. S. meteorological station at Point Barrow.

ROYAL UNITED SERVICE INSTITUTE JOURNAL.

No. CXII. Naval intelligence and protection of commerce in war.

The great and increasing dependence of Great Britain upon foreign countries for her daily bread has extended the scope of the question of national defence beyond the "marine league from shore."

The importance of systematic action on the part of the navy, in protecting and policing the great highways of British commerce, in the most efficient manner, is

the argument of this very interesting paper, by Capt. J. C. R. Colomb. The English people, while deeply interested in the volunteer question, the militia, the permanent seacoast defences, and the massing and manœuvring of troops—subjects which the late wars on the Continent have kept before the public—have lost sight of the vital importance of strategy on the sea, as well as on land. The collection of naval intelligence on the entire continent of Europe has been confided to one officer, while its scope is so great as might well employ the time and ability of a distinct bureau, possessing the means of obtaining useful information in all parts of the world.

The extent and variety of information which should be collected, tabulated and always available, is sketched by Capt. Colomb, and divided into two heads, as covering the main duties which a navy is called upon to perform in the event of war: (1) information in relation to blockade, and (2) information in relation to the direct protection of commerce. To the latter head Capt. Colomb devotes his chief attention.

Common to both are matters pertaining to hydrography, meteorology, the naval policies and resources of foreign nations, and everything relating to construction, armament, *personnel*, and, in fact, those strictly professional points upon which the naval authorities of all nations should be as well posted as may be; but such facts as will insure a readiness to protect the extensive commerce of Great Britain in the event of a call to arms, are of a more varied character, and not always so easily attainable. Such, for example, is a thorough knowledge of the condition, whereabouts and ownership of all steam vessels capable of conversion into war cruisers. The extent of information necessary to gather abroad, under this head, is not so great, however, as might be imagined, since Great Britain owns two-thirds of the steam tonnage of the world, while builders' statistics in that country would add considerably to that proportion.

The necessity for a system—independent of telegraph cables—for rapidly disseminating information is illustrated by an incident related as having occurred during the Crimean war—in the age of steam: "A Russian frigate (on a certain station) rode at anchor in the middle of an English squadron months after the Guards had been cheered through the streets of London on the way to the East. Seven weeks after her parting company with the English squadron, she passed on the high seas under the stern of an English vessel of war," the latter "dipping her ensign to the frigate of a power we had been fighting for months."

With the aid of tables and block diagrams, Captain Colomb discusses the relative values to Great Britain of the several ocean districts. Exemplifying his plan by a sketch map of the Atlantic ocean, he plots six strategic circles, varying in diameter from four hundred to eight hundred miles, and placed at the crossings of the great ocean lanes which are traversed by steam as well as by sailing vessels. These circles he proposes to occupy and protect, the intervals to be patrolled, thus keeping up a constant communication between the detached squadrons. By means of a thorough system of intelligence, the departure of grain vessels from Oregon or Australia is known weeks in advance to the commanders of squadrons, and the time of their arrival at the equatorial crossing estimated. The idea is ingeniously worked out by the lecturer. As to the old convoy system, as it might be adopted in an emergency by the Admiralty with its present knowledge and preparation, he says: "Picture the scenes on 'change in London, Manchester, Liverpool and hundreds of business centres in England, to say nothing of Sydney, Montreal, Melbourne, Calcutta, Cape Town, etc., which would follow the posting up of an admiralty notification that the imperial sea-roads were so interrupted that arrangements were under immediate consideration to provide, so far as means would permit, convoy protection for eight hundred millions worth of exports and imports, and the entry, clearance and safe passage of several million tons of British shipping from and to ports on every sea and ocean in the world."

Capt. Colomb's plan for collecting intelligence is to create a commercial intelligence council, representing the shipping and the chief export and import interests, to be presided over by an Admiral with a seat at the Admiralty Board.

He closes his paper with a practical suggestion for testing the present efficiency of the fleet in the event of one commerce-destroying cruiser being at large.

A new system of hydraulic propulsion, by Vice-Admiral Selwyn.

No. CXIII. Recent experiments in screw propulsion.

In No. CI. of the Journal appeared a paper by Mr. Robert Griffiths, C. E., in reference to the advantage of placing the screw a suitable distance abaft the stern-post, and clear of the run. The present paper, by the same author, describes several methods of adapting the ordinary stern and screw frame to such change.

SOCIÉTÉ DES INGÉNIEURS CIVILS.

MÉMOIRES, SEPTEMBER, 1881. Hydrocellulose.

Hydrocellulose is in the intermediate state of hydration through which cellulose materials pass before saccharification when they are submitted to the action of acids under determined conditions. It possesses most of the properties of normal cellulose, but it is very friable, like the pyroxylins. These friable pyroxylins are of two kinds following the mode of preparations. Those obtained through the action of cold concentrated acids are explosive; those obtained with hot concentrated acids are soluble in ether and alcohol. The method for the production of hydrocellulose and the friable photographic pyroxylin is treated of at length.

OCTOBER. Meetings at the electrical exhibition.

This contains a description of the various machines and motors exhibited, and a valuable and full statement of the units of electrical measure adopted, with discussion of their relations and values in absolute units.

NOVEMBER. Electric railway, Siemens' system.

In an address made by M. Boistel an interesting account is given of the electric railway at the Paris exhibition. It was first exhibited at Berlin in 1879. The general system there employed was to have a dynamo-electric machine at one end of the line worked by a steam machine, the current from which passed through the rails to a car containing a Gramme machine, which was worked backward by the current, the return circuit being made by a third rail, between the two others. In this case it was found that the wooden ties afforded sufficient insulation, but the current would of course be short-circuited by any connection between the centre and either of the side rails, and persons and horses occasionally received powerful shocks in this way.

At Berlin the railway ran through a park comparatively unfrequented, but at Paris it was laid in front of the Palais de l'Industrie in a street of constant travel. In order to avoid all chance of accidents, as well as to preserve the machines from the injury that resulted from short circuiting, the attempt was made to use an elevated wire for the return current. More difficulty was then experienced from the accumulation of dust and gravel on the rails, preventing good contact with the wheels, thus endangering the primary machine and sometimes bringing the car to a stop. It was found necessary to make the whole circuit aerial, and brass tubes of about 22 mm. diameter were used for the conductors. These tubes had a slot in the lower part, and contained small sliding pieces of brass, from which rods were hung, passing through the slot in the tube and connecting with cables which conveyed the current to the machine in the carriage. This arrangement was awkward, but answered its purpose well, although involving a loss of considerable power. The armature of the car machine worked one pair of wheels by gearing. The primary machine, a Gramme, made 500 revolutions per minute, being worked by an engine of 20 horse-power, the car machine making 465 and the wheels 116, corresponding to a speed of 17 kilometres an hour. The power transferred to the car was estimated as 8 horse-power.

Under the car platform was placed a set of resistance coils, in the main circuit. When going at full speed these could be cut out, and introduced in part

or in whole when necessary to slow down or stop, a hand brake being used in addition in the latter case. For stopping a commutator had been arranged so that the current could be cut off the machine and applied to work the brake electrically, but this was found to be too violent in its action. The experiments were made under unfavorable circumstances, and the power was received in such a way as to prevent any accurate calculations of the energy utilized or its cost, but M. Boistel thinks it cheaper than any other. Experiments are to be made in Paris on an elevated road, supported on insulated columns, from which better results will unquestionably be obtained, and there can be but little doubt that under favorable circumstances the system can be made a success, although to be of practical utility it must compete economically with other motors.

BOOKS RECEIVED.

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American Geographical Society. Bulletin No. 2 of 1881.

American Metrological Society. Proceedings, Vol. II.

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Franklin Institute Journal, Oct., Nov., Dec., 1881.

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Institution of Mechanical Engineers. Proceedings, Aug., Oct., 1881.

Mittheilungen a. d. Gebiete d. Seewesens. Vol. IX., Nos. 10 and 11.

Moniteur de la Flotte. Nos. 44–53, 1881.

New York Genealogical and Biographical Record, Vol. XI., No. 3.

Popular Science Monthly, Nov., Dec., 1881.

Rèunion des Officiers. Bulletin Nos. 45–53, 1881.

Rivista Marittima. Oct.–Nov., Dec., 1881.

Royal United Service Institution. Journal, Nos. CXII, CXIII.

School of Mines Quarterly, Vol. III., Nos. 1 and 2.

Société des Ingénieurs Civil. Mémoires, Sept., Oct., Nov., 1881.

NAVAL INSTITUTE PRIZE ESSAY, 1883.

A Prize of one hundred dollars and a gold medal of the value of fifty dollars is offered by the Naval Institute for the best essay presented, subject to the following rules:

1. Competition for the prize is open to all members, and to all persons entitled to become members upon payment of dues; that is, to all officers of the Navy and Marine Corps, and to all civil officers attached to the Naval service. But members who have been dropped for non-payment of dues are not eligible for membership until their arrears of dues have been made good.

2. Each competitor to send his essay in a sealed envelope to the Secretary on or before January 1, 1883. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments, to be selected by the Executive Committee, who will be requested to designate the essay, if any, worthy of the prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful essay to be published in the Proceedings of the Institute, and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Executive Committee.

5. Any essay not having received honorable mention, to be published only with the consent of the author.

6. The subject for the Prize Essay is, "*How may the sphere of usefulness of Naval Officers be extended in time of peace with advantage to the country and the Naval Service?*"

7. The Essay is limited to forty-eight printed pages of the "Proceedings of the Institute."

8. The money value of the medal may be given to the successful competitor if he so elect, and he will be made a life member of the Institute.

CHAS. M. THOMAS,
Secretary.

ANNAPOLIS, MD., *March* 9, 1882.